



EXPLANATION OF PLATE

Trypanoplasma, probably *T. borreli*. All the figures with the exception of Figure 1, which is a free-hand drawing, were drawn with the camera lucida, using a Leitz 2 mm. apochromatic objective and compensating ocular $\times 18$. They have been reproduced at a magnification of 2,600 diameters. Figures 2-6 were drawn from smears fixed with osmic acid vapor, stained with Giemsa's azur-eosin and mounted in neutral Canada balsam.

Fig. 1. Drawn from a living specimen in a fresh preparation of the blood.

Fig. 2. From blood from the kidney.

Fig. 3. From blood from the heart.

Figs. 4 to 6. From blood from the kidney.

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ON THE OCCURRENCE OF A TRYPANOPLOASM, PROBABLY *TRYPANOPLASMA BORRELI* LAVERAN ET MESNIL, IN THE BLOOD OF THE COMMON SUCKER, *CATOSTOMUS COMMERSONI*¹

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In spite of the considerable interest in the distribution of the hemoflagellates, there is no record, so far as the writer is aware, of a trypanoplasma occurring in the New World. The species to be described seems to be identical with *Trypanoplasma borreli* described by Laveran and Mesnil (1902). This species is reported to cause disease and death in fish in captivity, but no case is recorded of a trypanoplasma causing a pathogenic condition in a fish in the wild state, where there is little opportunity for more than a single infection. On this account the facts to be recorded are of special interest.

The sucker in which the trypanoplasma was found was seen in shallow water at a wharf in Go Home Bay, a small bay leading from the Georgian Bay, about twenty miles from Penetanguishene, Ontario. The fish was sluggish and allowed itself to be easily picked up in a dip net. When brought to the laboratory and taken out of the water it died in a few minutes. There were no external lesions and no abnormalities were discovered in a hasty examination of the viscera. The gills were pale and bloodless. Preparations of blood from the heart showed the presence in great abundance, one or two in a single field of the immersion objective, of the trypanoplasma to be described.

As the Biological Station was about to be closed for the season it was possible to obtain only one other sucker, which was caught in a fyke net. This was active and normal in every way. In five fresh preparations of the blood from the gills, the heart, and the liver no hemoflagellates were found after a careful search.

The evidence available in this case is scarcely sufficient to prove the trypanoplasma as a specific cause of the pathogenic condition of the

1. The observations in this paper were made while the writer was curator of the Biological Station of the Canadian government at Go Home Bay, near Penetanguishene, Ontario, in 1913. The courtesy of the directors of the Biological Board of Canada permits their publication here.

fish. The parasite is interesting, however, in that it occurs in a fish in the wild state, where there is little probability of there being more than a single, or at most, a few infections, the parasite being without doubt carried by a leech. There is no record, so far as the writer is aware, of a trypanoplasm causing a pathogenic condition in a fish in the wild state. Such a condition, however, has been recorded for fish in captivity, and if, as the author is inclined to believe, the parasite of the sucker is *T. borreli*, for the same species of parasite. In carp, *Cyprinus carpio* L., infected with *T. borreli*, Marianne Plehn (1904:175) finds: "Bei stark befallenen Fischen erreicht die Anämie einen ganz extremen Grad; man kann nur wenige Tropfen eines wässerigen, kaum rötlichen Blutes gewinnen; Keimen und innere Organe sind äusserst blass. Andere pathologisch-anatomische Merkmale fehlen. Die Tiere zeigen in der letzten Lebenszeit ausser beschleunigter Atmung und grosser Unlust sich zu bewegen nichts Auffälliges. Sie gehen offenbar an Blutmangel ein, den sie, zwar lange, aber doch nicht dauernd ertragen können. Es ist unzweifelhaft, dass die Krankheit auch im Freien Schaden anrichten wird; die Beobachtungen sind noch zu jungen Datums um allgemeine Angaben über Verbreitung und Bedeutung zu gestatten." Keysselitz (1906) has also described the pathological condition in the carp due to *T. borreli*. Leger (1904:824) describes cases of acute infection of the minnow, *Phoxinus laevis* Agass, with a trypanoplasm as follows: "Des infections aussi intenses amènent chez le poisson une anémie profonde: décoloré et enflé il se tient immobile, refuse toute nourriture et finit par mourir." A case in which a trypanosome may cause a pathogenic condition has been recorded by Doflein. He remarks (1909:398), referring to *Trypanosoma carassii*: "Ich selbst hatte allerdings einmal Gelegenheit, eine sehr ähnliche, vielleicht sogar identische Art im Blut der Schleie, *Tinca vulgaris*, zu beobachten; die befallenen Schleien waren offenbar krank, sie waren sehr apathisch und waren an die Station zur Untersuchung von Fishkrankheiten in folge eines grossen Sterbens in den betreffenden Weihern eingesandt worden."

The terminology used in this paper is that used by Minchin (1912), with the exception of the term "basal granule," which has been used in place of the term "blepharoplast," as used by that author.

As seen in the living state (Fig. 1), the trypanoplasm has the form typical of the genus; a thick yielding body with two flagella, one of which forms the border of an undulating membrane. The measurements of the body are, length 20-25 μ , thickness 3-4 μ . The anterior flagellum is between one-half and two-thirds as long as the body. The posterior flagellum arises near the anterior flagellum and passes posteriorly, forming the margin of the undulating membrane. It extends

freely for about two-fifths of its length beyond the posterior end of the body. The undulating membrane is comparatively thick and not sharply distinguishable from the edge of the body. The parasites showed an active writhing motion, but little progression. What there was seemed to be with the morphologically posterior end in advance. The protoplasm was finely granular, a few larger highly refractive greenish granules measuring up to $0.4\ \mu$ in their longest diameter, being present in the posterior half (Fig. 1). After the preparation had been standing for a little time, sealed with vaselin, two or three large vacuoles were seen in the posterior end of some individuals.

Smears of the blood from the heart and from the kidney were fixed in the vapor of osmic acid, stained with Giemsa's azur-eosin and mounted in Canada balsam neutralized with lithium carbonate. In each of the smears the trypanoplasma was found to be abundant. Although often much distorted, the parasite is found in some parts of the smears remarkably well preserved. It is to be regretted that when the parasite was discovered time did not permit of the making of "wet" smears stained with hematoxylin. The results especially as regards the kinetonucleus are open to criticism on that account.

About fifty of the best-preserved and most clearly showing individuals have been studied in detail with a 2 mm. apochromatic objective and compensating oculars 12 and 18. The parasites show great uniformity in size and general structure. They are nearly always sickle-shaped, the trophonucleus and the undulating membrane being on the convex side. Measurements show little or no difference in size between fresh and preserved individuals.

The protoplasm, as in the fresh preparations, is finely granular and contains a varying number of relatively large, deeply staining granules distributed either mainly in the posterior end (Fig. 3), or irregularly throughout its extent (Figs. 4, 5). It is possible that these larger granules are identical with the greenish granules observed in fresh preparations. Such "chromatoid granules" have been found in different species of trypanoplasms (Leger, 1904; Keysseltz, 1906; Friedrich, 1909; Minchin, 1909). It is doubtful whether these granules are chromidial in nature.

The anterior flagellum arises at the extreme anterior end and on the side of the body on which the kinetonucleus is located. It leaves the body independently of the posterior flagellum (Figs. 4, 5). The posterior flagellum arises very close to the anterior and passes around the blunt anterior end and along the entire length of the body as the margin of the undulating membrane (Figs. 1, 2). It is continued posteriorly as a free flagellum of a length equal to about two-thirds that of the body. The undulating membrane shows in some cases as

a clear unstained area between the posterior flagellum and the granular protoplasm of the body (Figs. 2, 4).

The kinetonucleus (Woodcock, 1909, for the "Geisselkern" of German authors) is situated on the side opposite to the trophonucleus and the undulating membrane and about one-third of the length of the body from the anterior end. It has a clear outline and stains deep purple, in contrast to the more reddish tinge of the trophonucleus. In the individuals which show least distortion it is ovoid, about half again as long as it is wide and shows a distinct membrane. Its size varies between wide limits (Figs. 2-5). Its usual size, however, is 3.5 by 2.4 μ . When not too deeply stained five or six deeply staining bodies can be seen lying immediately under the membrane. In some cases what appears to be two kinetonuclei are present in individuals which show no division of the flagella or trophonucleus (Figs. 3, 5). In such cases each of the two bodies shows a clear contour and is undoubtedly surrounded by a membrane. Each also shows the included stained granules, as in the case of the single kinetonucleus, but the number of granules in each is less than in the single kinetonucleus. The two bodies may be of almost equal size, or one, always the anterior, may be much the smaller (Figs. 3, 5); they may be near together or far apart.

That this dual nature of the kinetonucleus is due to faulty technic seems hardly possible, in view of the fact that the two parts are surrounded by distinct membranes. It may be that it is due to division, the kinetonucleus, in this case, having completely divided before either the flagella or trophonucleus. Against this assumption are the facts: first, that the individuals show no other signs of division, unless, which is doubtful, the presence of two basal granules is to be taken as such; and second, that the two parts of the kinetonucleus are often of very unequal size.

Keysselitz (1906) finds in *Trypanoplasma borreli* Laveran et Mesnil that the "blepharoplast" (kinetonucleus) divides transversely, but says (p. 32): "Ein zeitlich gesetzmässiges Verhalten zwischen der Teilung des Kernes und Blepharoplasten kann ich nicht konstatieren." Friedrich (1909:385) finds that the division of the kinetonucleus is "eine einfache Längsspaltung." His figures 19 and 22 show that it may divide before either the trophonucleus or the flagella. Martin (1910) finds in *Trypanoplasma congeri* Elmhirst and Martin that the divisions of the flagella and the trophonucleus precede that of the kinetonucleus.

The condition found in the blood of *Catostomus commersonii* seems to resemble most closely that described by Keysselitz (1906:25) for *Trypanoplasma borreli* in "geschwächten anämischen Fischen" (see his Figs. 40, 42, 45i). Here, however, the kinetonucleus may be divided

into more than two parts. In this connection it will be remembered that the sucker in which the trypanoplasma was found showed an anemic condition similar to that described by Keysselitz. The same author (1906:37 and Fig. 47) finds in a parasite of the stomach and adjacent parts of the alimentary tract, "Bei *Trypanoplasma ventriculi* weist der Blepharoplast sehr häufig eine Sonderung in zwei Stücke auf." Laveran and Mesnil (1902) in their description of *T. borreli* figure two individuals (p. 491, Figs. 13 and 15), each with two kinetonuclei. (Although Laveran and Mesnil considered these bodies to represent the trophonucleus "le noyau" and not the "centrome des Trypanosoma," there is no doubt that they were mistaken.)

Two basal granules (centrioles, blepharoplasts of Minchin, 1912) are usually to be seen where the flagella arise. They stain deeply and are to be distinguished only by their position from the chromatoid granules found in other parts of the protoplasm. Although the ends of the flagella can in certain animals be seen to enter the protoplasm separately (Figs. 4, 5, 6), they cannot be traced to separate granules (Figs. 4, 5).

The trophonucleus is situated about a third of the length of the animal from the anterior and often lies side by side with the kinetonucleus (Figs. 2, 3, 5); in other cases it is slightly behind the kinetonucleus (Figs. 4, 6). Its shape and size resemble that of the kinetonucleus, being however usually slightly smaller. It is ovoid and measures on the average 2 by 3 μ . In many cases it shows a distinct membrane (Figs. 2, 4). In other cases such a membrane was not to be seen, probably on account of poor fixation. It contains a varying number of deeply staining granules. In some cases one of these granules (karyosome?) is larger and centrally located.

So far as the writer is aware the genus *Trypanoplasma* has been described only from European fishes. The species recorded as occurring in the blood are:

- T. abramidis* Brumpt 1906.
- T. barbi* Brumpt 1906.
- T. borreli* Laveran et Mesnil 1902.
- T. cyprini* Plehn 1904.
- T. guernei* Brumpt 1906.
- T. gurneyorum* Minchin 1909.
- T. keysselitzii* Minchin 1909.
- T. truttae* Brumpt 1906.
- T. varium* Leger 1904.^a

The species *abramidis*, *barbi*, *cyprini*, *guernei*, *gurneyorum* and *truttae*, as described by their authors, have a rod shaped kinetonucleus and the free portion of the posterior flagellum either half as long

(barbi) or less than half as long as the anterior flagellum; two characters which exclude the *Trypanoplasma* of the sucker. The latter differs, also, from *T. keysseltzi* which has the two nuclei near together at the anterior end and the kinetonucleus "very elongated". There seems some doubt as to whether *T. varium* is not the same species as *T. borreli*, the chief argument of Leger (1904^a) being that the two forms show a preference for different hosts.

The trypanoplasm found in the sucker has all the morphological characters described and figured for *T. Borreli* by Laveran and Mesnil (1902), size and shape of the body, position and shape of the nuclei, and length of the flagella. The writer therefore provisionally identifies it with this species.

It is interesting to note that German carp, in which Keysseltz (1906) has studied *T. borreli*, have been introduced into the Canadian lakes and occur near where the sucker was found. *Catostomus commersonii* and *Cyprinus carpio* are closely related fish, being in the same family, Cyprinidae.

It is therefore not improbable that *T. borreli* has been introduced into the Canadian lakes with the German carp.

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TWO NEW CASES OF POLYRADIATE CESTODES, WITH A SUMMARY OF THE CASES ALREADY KNOWN

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Anomalies in adult cestodes are by no means uncommon and have been reported by numerous investigators in the last two centuries. These may be divided into those which affect only part of the worm and those which are characteristic of the entire strobila. Among the former are supernumerary proglottids, fenestrated segments, bifurcation of the strobila at the posterior end, branching at the side, forming a short chain of proglottids arising from a supernumerary proglottid, fusion of the line of separation of the proglottids through part of the strobila, and inversion of the usual arrangement of the sexual organs. Supernumerary proglottids are usually formed by the insertion of a smaller incompletely developed proglottid, into an otherwise normal proglottid (Fig. 1) or the supernumerary proglottid may be triangular and extend the entire length of the lateral edge of the proglottid to which it is attached. Fenestrated proglottids in which the central portion of the parenchyma is lacking are usually confined to a few segments, but in a few cases have involved nearly all the segments of the strobila. Fusion may be complete throughout a large number of proglottids or the line of demarcation between the proglottids may be obliterated only partially, giving the appearance of an excessively long proglottid on one side and two or more normal proglottids on the other, as in McCulloch's (1913) case.

Of more immediate interest are the cases of triradiate strobilae, in which the entire strobila instead of being flat or ribbon like, as in the normal tapeworm, has a central ridge extending uniformly throughout all the proglottids and giving a triradiate figure when seen in cross-section. This anomaly may also be combined with the anomalies affecting individual proglottids mentioned in the preceding paragraph. Twenty-eight such cases have been collected by Vigener (1903) and are summarized in the accompanying table. To this list I have added five more cases, one of them not hitherto reported.

EXTERNAL ANATOMY OF POLYRADIATE CESTODES

Analogous to the triradiate forms are those in which the tapeworm has more than three wings. Such forms are far less common, and if we except Leuckart's case (1880), which he considered as a fusion

of two triradiate forms, but which Barrois (1893) concludes is a case of simple triradiate proglottids having a simple supernumerary proglottid attached to one of the wings, only one case (Rosenberger, 1903) has hitherto been reported. In Rosenberger's case the parasite was pentaradiate, forming a star-shaped figure. As Rosenberger, however, does not specify the exact shape of the proglottids other than to describe them as "star shaped," and as his observation was published in a journal not readily accessible to European helminthologists, it has been largely overlooked and the existence of strobilae having more than three wings is not mentioned in any of the text-books. In the present paper a tetraradiate proglottid of *Taenia saginata* is described. The term *polyradiate* is suggested as a convenient word for describing all cases of adult cestodes in which the strobila is formed of three or more wings radiating from a common axis.

With but one exception, all triradiate cestodes in which the head has been recovered have been found to have six suckers instead of the usual four; the triradiate feature extending throughout the scolex, as is well seen in Vigener's (1903) case. In Rudolphi's (1810) case, however, the scolex is described as normal. Considering that the principal feature of this anomaly is its uniformity throughout the entire strobila, and that Rudolphi's case is the only exception recorded, the correctness of his observation has been questioned. It is therefore logical to assume that a cysticercus with six suckers represents the larval stage of a triradiate cestode, and this view is generally accepted by helminthologists. Such cases are included in Vigener's (1903) list of triradiate cestodes on which the present table is based.¹ In all, forty-four cases of polyradiate cestodes (larvae and adults) have been reported. The number of individual specimens reported is, however, much greater, since two writers, Zürn (1898) and Railliet (1899), report seeing "several" larval cestodes having six suckers, and three other writers each describe two or more adult specimens.

By far the greater number of polyradiate forms are found in *Taenia saginata*, twenty-four adult cestodes of this form having been described. Of these twenty-four cases, two (Andry, 1741, and Brera, 1811) are so indefinite as to be doubtful, and in four other cases the distinction between *Taenia solium* and *Taenia saginata* has not been made. These cases are assigned to *T. saginata*, since this parasite is more common than *T. solium* in the regions where the cases were observed. Among the twenty-four cases is one pentaradiate form (Rosenberger, 1903) and one tetraradiate (Foster, the present paper).

1. Vigener's article includes a complete bibliography of all cases of triradiate cestodes then known.

In four species, *Taenia saginata*, *T. solium*, *T. pisiformis*, and *T. coenurus*, larval forms with six suckers have been found as well as the adult triradiate forms. Summarizing the cases the number of individual specimens reported are:

Adult cestodes		Larval cestodes	
Species	Number	Species	Number
<i>Anoplocephala perfoliata</i>	1	<i>Coenurus cerebralis</i>	2
<i>Bothriocephalus latus</i>	1	<i>Coenurus serialis</i>	Several
<i>Bothriocephalus tectus</i>	Several	<i>Cysticercus bovis</i>	1
<i>Dipylidium caninum</i>	1	<i>Cysticercus cellulosae</i>	2
<i>Taenia coenurus</i>	3	<i>Cysticercus pisiformis</i>	1
<i>Taenia echinococcus</i>	1	<i>Cysticercus tenuicollis</i>	Several
<i>Taenia pisiformis</i>	1		
<i>Taenia saginata</i>	24		
<i>Taenia solium</i>	2		
<i>Taenia taeniaeformis</i>	2		

It appears from the column in the table showing the localities where polyradiate cestodes have been found that this anomaly is as widespread as the geographical distribution of the cestodes themselves. That more cases have been reported from Germany and France than elsewhere, is apparently due to the greater attention which has been given to the subject of teratological forms in these countries.

In most cases of adult polyradiate cestodes the scolex has not been recovered. Twenty-four writers have recorded cases of *Taenia saginata*, but five of them only have observed the head. This is probably due to the fact that these specimens were recovered from the living hosts by vermifuges instead of at autopsy, and were therefore more liable to damage. The fact that cases of polyradiate cestodes have been found far more commonly in *Taenia saginata* than in other species may be due to a greater frequency of variation characteristic of this species, as suggested by some helminthologists, but may also be explained by the fact that this species, being a common parasite of man, is perhaps more frequently observed than any other species. This opinion is supported by the fact that most of the cases are reported by practicing physicians who have many opportunities to observe this species and little chance to study other species not parasites of man. If this species were especially subject to this anomaly we should expect to find a correspondingly large number of *Cysticercus bovis* with six suckers, yet only one such case has been reported.

A triradiate cestode usually has an unpaired wing, smaller than the other two wings, which are usually of nearly equal size. Sometimes these equal wings lie close together, as in MacCallum's (1912) case, giving the worm the appearance of a normal cestode split lengthwise through half its width. Usually, however, the wings are thickened at the base so that they are separated from one another, giving a tri-radiate appearance. The unpaired wing may be so reduced as to form a mere ridge along the center of an otherwise normal parasite, as in

Jelden's (1900) case, or it may be so well developed as to be equal in size and symmetry with the other wings, giving a perfectly symmetrical figure, as in Yoshida's (1913) case.

The number and arrangement of the genital pores are subject to considerable variation. In most cases there is a single pore in each segment, located on the margin of the unpaired wing. Thus all pores are unilateral, an arrangement in striking contrast with the normal arrangement in the genus *Taenia* in which the pores are irregularly alternate. There are, however, many exceptions to this rule. In Bremser's (1819) case of *T. saginata*, according to Rudolphi (1819) the genital pore was in most cases located on the unpaired wing, but three variations were seen: (1) genital pore not on the unpaired wing but on the edge of one of the paired wings; (2) genital pore on the unpaired wing and on the edge of one of the two paired wings; (3) genital pore on the unpaired wing and on each of the paired wings. Two proglottids each had two genital papillae on the same unpaired wing, one located anteriorly, the other posteriorly. In Küchel's (1892) case, according to Vigener (1903), who re-examined his material, one segment bore three papillae and several segments had two sexual openings. As a rule there was but one sexual opening to each proglottid on the edge of any one of the three wings. In Bork's (1891) case although the unpaired ridge was papilliferous throughout, a supernumerary proglottid had a genital pore in the crevice between two of the wings. In Yoshida's (1913) case of *Taenia taeniaeformis* (*T. crassicollis*), "the genital pore is usually single in each segment, situated on any one wing of the worm, but there are sometimes two genital pores lying respectively on any two wings of the segment". In von Linstow's (1892) case of *Bothriocephalus tectus*, the genital pores are all situated on the middle line of the ventral surface, the normal position for cestodes of this genus.

The triradiate form in cestodes is not infrequently associated with the more common anomalies of supernumerary proglottids, forking, and fenestration. Both forking and supernumerary proglottids were observed by Vigener (1903) and Cattaert (1899). In the cases of Cattaert (1899) and Coats (1891), the worm ends in a triple fork, each branch forming one wing of the triradiate strobila. In McCulloch's (1913) case both fenestrated and supernumerary segments were frequent. The fenestration involved only mature segments, usually extending through two adjacent segments and following the line of the unpaired ridge. Asymmetrical segments were formed by the line of division between segments extending through only one or two of the three lateral wings, the opposite wing or wings being equal in length to the sum of these asymmetrical segments.

INTERNAL ANATOMY

The internal anatomy of polyradiate cestodes does not as a rule, present any special variation from the normal except in so far as the arrangement of the organs is associated with the peculiar external form. The extra wing or wings are as fully developed internally as the normal part of the cestode. The uterus, having its main stem running through the center of the polyradiate proglottid, sends off lateral branches into each of the wings irrespective of their relative size. Thus in Jelden's (1900) case, although the unpaired wing is here reduced to a mere ridge, it contains its full share of the uterine branches. The longitudinal excretory canals and longitudinal nerves, which in normal taeniae extend along each lateral margin of the cestode, are, in polyradiate forms, found in the same relative position in each of the wings. Several minor variations from the normal have been recorded. Both Neveu-Lemaire (1900) and Cattaert (1899) observed that the transverse muscle fibers at the point where the three wings separate occasionally formed a partition wall separating one wing from the other two. In Neveu-Lemaire's (1900) case the longitudinal canal in the unpaired ridge was larger than the other two. The ovaries lay in the posterior portion of the proglottid in the center of the "Y," ramifying into the two equal wings but not into the unpaired wing. Yoshida (1913) finds that in his specimen of *Taenia taeniaeformis*, the testes are distributed throughout the three wings and not confined to the dorsal side as in normal specimens of this species. The eggs of triradiate cestodes are usually reported as normal, but Küchel (1892) reports that out of ten eggs which he examined, one was normal, seven had eight hooklets arranged in pairs, and two had ten hooklets including one that was very small and incompletely developed.

THE WRITER'S CASE OF A TRIRADIATE TAENIA PISIFORMIS

Although Railliet (1892) has reported a case of *Cysticercus pisiformis* having six suckers, no case of an adult triradiate cestode of this species has yet been published. The present example was found in a mass of tapeworms expelled by an imported collie dog held at quarantine in Athenia, N. J., and treated with a taeniafuge for tapeworm infestation, which had been diagnosed from a microscopic examination. The mass of tapeworms received at this laboratory consisted of a great many fragments which were roughly estimated as belonging to from seventy-five to one hundred individuals, all of which, as far as examined, were of the same species, *Taenia pisiformis*. Although the entire mass was examined in a petri dish, no scolices were found. The identification of the species was verified by feeding experiments on a

rabbit. In this mass a number of chains of triradiate proglottids were found, the longest piece being 23 cm. representing the anterior half of the worm, except the head. In all about 52 cm. of the worm were recovered.

The parasite is uniformly triradiate throughout its entire length, the three wings being of almost equal size and having the same angle between them (Fig. 1). The wings are thickened at the base, thus maintaining the symmetry of the figure. Owing to shrinkage from

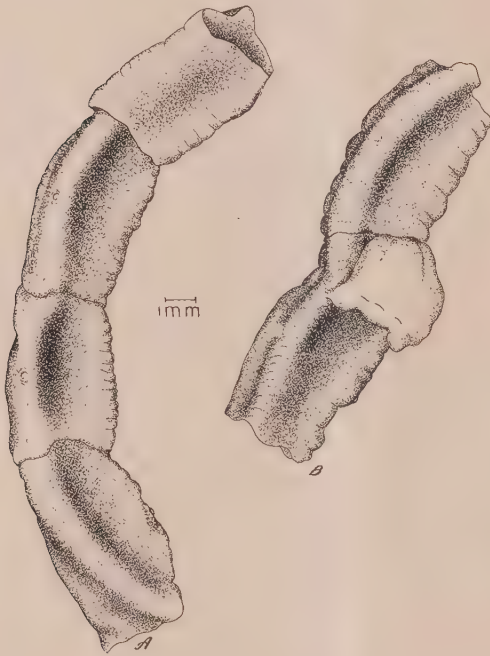


Figure 1

Fig. 1.—*A*. Portion of a triradiate *Taenia pisiformis*, showing the twisting of the strobila, and consequent displacement of the papilliferous wing. *B*. Another portion of the same specimen showing a supernumerary proglottid without genital pore. [Original.]



Figure 3

Fig. 3.—A tetra-radiate proglottid of *Taenia saginata*. *gp*, genital pore. [Original.]

the formalin in which the specimen was sent, the genital pores are very difficult to observe in unmounted proglottids. As far as could be determined, however, there is but one pore to each segment, and it is always on the edge of the same wing. Owing to a spiral twist extending irregularly throughout the greater part of the strobila, the papilliferous wing of a given segment is seldom in line with the same wing in the

adjacent segments. Thus in Figure 1 A, while the two middle segments have the papilliferous wing on top, in the bottom segment it is on the right-hand side, while in the upper segment it is underneath. That this shifting of the papilliferous wing is due to the spiral twist and not to the fact that the pore may be on any one of the three wings, is made evident by finding the pores all in a straight line in those parts of the strobila not affected by the spiral twist. The longest proglottid was 13 mm. long by 2.5 mm. wide. The average was 7 mm. by 3.5 mm. Only one supernumerary proglottid was seen (Fig. 1 B). This was

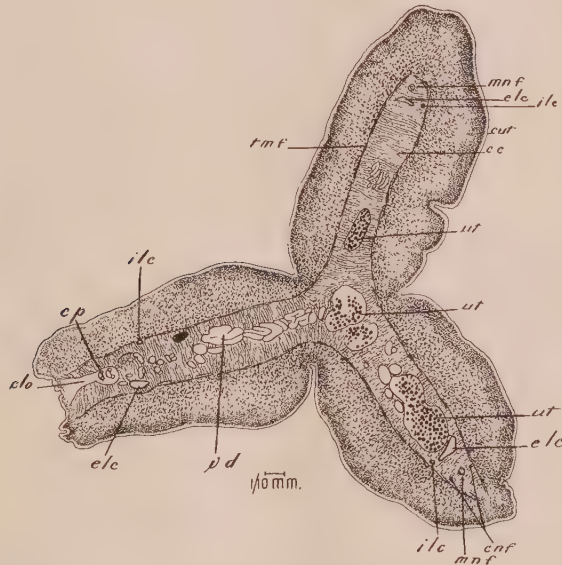


Fig. 2.—Cross section through a gravid proglottid of a triradiate *Taenia pisiformis*, in the region of the genital pore. *cc*, calcareous corpuscles; *clo*, cloaca; *cnf*, concomitant nerve fasciculi; *cp*, cirrus pouch; *cut*, cuticle; *elc*, external longitudinal canal; *ilc*, internal longitudinal canal; *mnf*, medullary nerve fasciculus; *tmf*, transverse muscle fibers; *ut*, uterus; *vd*, vas deferens. [Original.]

interpolated between two normal segments and affected only one wing, as the line of demarcation between it and the usual triradiate proglottid did not extend through all three wings. The supernumerary proglottid had no genital pore.

As in the other cases of triradiate cestodes, the sexual organs are found in all three wings. In ripe proglottids the uterus is seen to occupy the central portion of the body (Fig. 2), sending out branches into each wing. The eggs appear in all respects normal. Two longitudinal canals, the larger external and the smaller internal, appear in

each wing near the margin. The relative position of these canals varies both in different proglottids and in the different wings of the same proglottid. In the drawing (Fig. 2), the canals occur laterally, the ventral canal being much the larger. The principal longitudinal nerve, the medullary fasciculus, is between these canals and the margin of the wing, one in each wing. In one wing two accessory fasciculi could be seen on either side of the medullary fasciculus. The vas deferens at the plane of the section drawn occupies most of the medullary layer of one of the wings (Fig. 2), and, extending into the cloaca, passes between the two longitudinal canals. In mature proglottids the testes are distributed scatteringly throughout the three wings, being less numerous in the region of the vas deferens. As in normal proglottids, the ovaries occupy the central portion of the posterior half, and send out ramifications in all directions. The arrangement of the transverse and longitudinal muscle fibers, calcareous corpuscles and all other organs are, as far as observed, no different from that seen in normal cestodes of this species.

TETRARADIATE AND PENTARADIATE CESTODES

Only one case (Rosenberger, 1903) of an adult cestode having more than three wings throughout its strobila, has thus far been reported. That such an anomaly might exist was, however, anticipated by Railliet (1899), who examined a number of scolices of *Coenurus serialis* and found specimens having suckers ranging in number from three to ten. Railliet states in conclusion: "If the rule appears well established that a *Taenia* larva with six suckers will produce a worm with a triradiate chain, what malformation will arise from scolices having 3, 5, 8, 9, and 10 suckers?" In view of the assumed relation between the number of suckers of the scolex and the wings of the strobila, it is reasonable to suppose that Rosenberger's (1903) case of a pentaradiate *Taenia saginata* developed from a cysticercus with ten suckers, and that the present writer's case of a tetraradiate *Taenia saginata* was derived from an eight-suckered cysticercus.

Rosenberger (1903) received from a physician in Colorado a section of several proglottids of *Taenia saginata* having a "star-shaped" figure. The specimen was sent to Dr. Mohler of this bureau. Rosenberger's (1903) brief note includes a figure showing a chain of four proglottids having four equal or subequal wings radiating from a common center. As Rosenberger does not give the number of wings to his specimen and merely characterizes it as "star-shaped," the writer asked Dr. Mohler for further information. Dr. Mohler stated that according to his recollection there were five wings radiating from a common

center, giving the star-shaped figure described, and that the fifth wing did not appear in the drawing since it was hidden from view by the other wings. No detailed study was made of the specimen and the number and arrangement of the genital pores was not observed. Dr. Mohler was under the impression that the specimen had been deposited in the Helminthological Collections of the United States National Museum, but it could not be found. In looking through the material, however, a tetraradiate specimen was found, described below.

This specimen (No. 3269, Helminthological Collections, United States National Museum) consists of one proglottid only. The material was determined by Stiles in 1901 and collected the same year. Except for the name of the species (*Taenia saginata*) and the host,

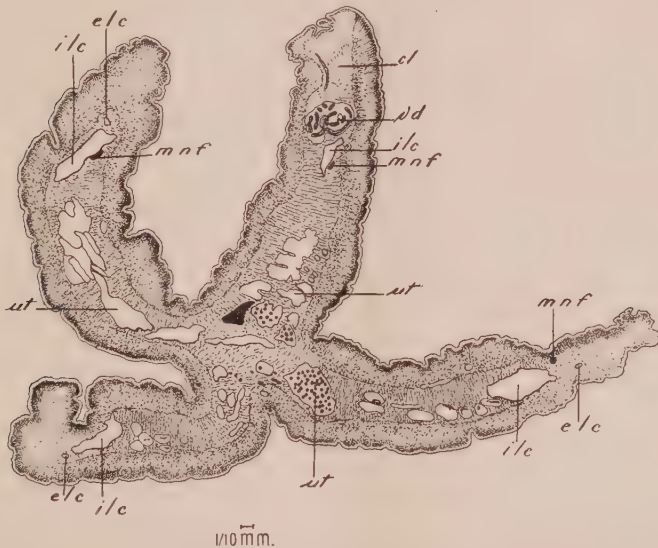


Fig. 4.—Cross section through a tetraradiate proglottid of *Taenia saginata*, in the region of the genital pore. *cl*, cloaca; *elc*, external longitudinal canal; *ilc*, internal longitudinal canal; *mnf*, medullary nerve fasciculus; *ut*, uterus; *vd*, vas deferens. [Original.]

no further information is given on the label. The proglottid is 15 mm. long with a maximum width of 8 mm. at the posterior extremity, which is considerably wider than the anterior end (Fig. 3). Three of the wings are of fairly equal width, the fourth wing, largely concealed in the drawing (Fig. 3), is considerably shorter than the others. There is but one genital pore, placed somewhat posterior to the middle of the segment, on the edge of the middle one of the three equal wings.

In cross-section (Fig. 4) the wings are seen to form an asymmetrical tetraradiate figure, the gravid uterus extending into each wing.

A large internal excretory canal of irregularly triangular outline is seen near the external edge of each wing. The smaller external canal appears between the internal canal and the outside edge. The uterine branches extending into all four wings are in most sections devoid of eggs and appear as large irregular lacunae in the medullary layer. A few eggs, however, appear in the main uterine stem (Fig. 4). The principal longitudinal medullary fasciculus is seen close to the wall of the internal canal, apparently flattened out by pressure from the adjacent longitudinal canal. The coiled vas deferens and the outline of the cloaca is seen in the middle of the three subequal wings.

ORIGIN OF POLYRADIATE CESTODES

Triradiate cestodes are sometimes referred to as being a fusion of two normal individuals; it would seem more logical, however, to consider them as representing the fusion of one cestode with half of another individual, since we invariably find six suckers to these triradiate forms and not eight, which we would expect if two individuals were blended. If, however, there were a true fusion we should expect to find a line of union, which does not appear in cross-sections. Moreover, if a cestode having irregularly alternate papillae were joined to another individual, we should expect to find about half of the proglottids with two genital pores and half with only one, yet it is usual to find only one genital pore to a segment, and that on the same wing throughout the strobila. From the fact that cysticerci with six suckers are occasionally found, and that oncospheres with more than six hooklets have been observed, it was suggested by Davaine (according to Railliet, 1899) that the cause of this abnormality originated in the egg. This view is, however, disputed by Leuckart (1880) and Railliet (1892), who point to the fact that in a coenurus, several of the scolices may have an abnormal number of suckers while the others are normal, yet all must have originated from the same oncosphere.

FEEDING EXPERIMENTS WITH TRIRADIATE TAENIA PISIFORMIS

In view of the fact that oncospheres with eight hooklets and cysticerci with six suckers have been found, it seems reasonable to expect that these forms would originate from a triradiate tapeworm, and Küchenmeister and Zürn (1878-81) and Railliet (1892) have suggested the advisability of feeding experiments to determine their origin. These authors were, however, unable to carry out the suggestion from lack of material.

Although the triradiate *Taenia pisiformis* described by the present writer was shipped in a solution of formalin of unknown strength, and kept in a 2 per cent. solution of formalin for one week after it

TABULAR LIST OF CASES OF POLYRADIATE CESTODES*

Author	Date	Species	Locality	No. of Specimens	Appearance of Head	Shape of Strobila
Andry	1741	<i>T. saginata?</i>	France	1	Unknown	Triradiate?
Rudolphi	1810	<i>Dipylidium caninum</i>	Germany?	1	Normal	Triradiate
Brera	1810	<i>T. saginata?</i>	Switzerland?	1	Unknown	Triradiate?
Bremser	1819	<i>T. saginata?</i>	Austria?	1	Missing	Triradiate
Bremser	1819	<i>T. taeniaeformis</i>	Austria?	1	6 suckers	Triradiate
Levacher	1841	<i>T. saginata?</i>	France	1	Unknown	Triradiate
Siebold	1853	<i>T. echinorococcus</i>	Germany?	1	6 suckers	Triradiate
Küchenmeister	1855	<i>T. coenurus</i>	Germany?	2	6 suckers	Triradiate
Küchenmeister	1855	<i>T. saginata</i>	Cape Good Hope	1	Missing	Triradiate
Zenker	1861	<i>T. solium</i>	Germany?	1	6 suckers	Triradiate
Krause	1863	<i>C. cellulosa</i>	Germany	1	6 suckers	Triradiate
Cobbold	1866	<i>T. saginata</i>	England	1	Missing	Triradiate
Vaillant	1870	<i>T. saginata?</i>	France	1	Missing	Triradiate
Cullingworth	1873	<i>T. saginata</i>	England	1	Missing	Triradiate
Küchenmeister & Zürn	1878-1881	<i>C. cerebrealis</i>	Germany	2	6 suckers
Leukart	1880	<i>T. coenurus</i>	Germany	1	6 suckers	Triradiate
Leukart	1880	<i>T. saginata</i>	Germany	1	Missing	Triradiate
Laker	1885	<i>T. solium</i>	Germany	2	6 suckers	Triradiate
Trabut	1889	<i>T. saginata</i>	Tonkin	1	6 suckers	Triradiate
Neumann	1890	<i>Anoplocephala perforiata</i>	France	1	6 suckers	Triradiate
Coats	1891	<i>T. saginata</i>	Scotland	1	Missing	Triradiate
Bork	1891	<i>T. saginata</i>	Germany	1	Missing	Triradiate
Railliet	1892	<i>C. pistiformis</i>	France	1	6 suckers
Küchel	1892	<i>T. saginata</i>	East Africa?	1	6 suckers	Triradiate
v. Linstow	1892	<i>Bothriocephalus tectus</i>	{ S. Georgia Antarctic reg.	Several	Missing	Triradiate
Monticelli	1893	<i>T. saginata?</i>	Italy?	1	Missing	Triradiate
Barrois	1893	<i>T. saginata</i>	France	1	Missing	Triradiate
Pittard (after Railliet)	1895	<i>Bothriocephalus latus</i>	England?	1	Unknown	Triradiate
Shennan	1898	<i>T. saginata</i>	Scotland	1	Missing
Klepp	1898	<i>C. cellulosa</i>	Germany	1	6 suckers
Zürn	1898	<i>C. teruicollis</i>	Germany	Several	6 suckers
Railliet	1899	<i>C. serialis</i>	France	Several	2, 3, 6, 8, 10 suckers
Cattaert	1899	<i>T. saginata</i>	France	1	Missing	Triradiate
Neveu-Lemaire	1900	<i>T. saginata</i>	France	2	1 case none 2 cases, 6 suckers	Triradiate
Jelden	1900	<i>T. saginata</i>	Germany	1	6 suckers	Triradiate
Lohoff	1902	<i>C. bovis</i>	Germany	1	6 suckers
Vigener	1903	<i>T. saginata</i>	Germany	1	6 suckers	Triradiate
Rosenberger	1903	<i>T. saginata</i>	Colorado, U.S.A.	1	Missing	Pentradiate
Galli-Valerio	1909	<i>Coenurus serialis</i>	Switzerland?	1	6 suckers
MacCallum	1912	<i>T. saginata</i>	Canada	1	Missing	Triradiate
Yoshida	1913	<i>T. taeniaeformis</i>	Japan	1	6 suckers	Triradiate
McCulloch	1913	<i>T. saginata</i>	Missouri, U.S.A.	1	Missing	Triradiate
Foster	1915	<i>T. saginata</i>	U. S. A.?	1	Missing	Tetradiate
Foster	1915	<i>T. pistiformis</i>	Europe	1	Missing	Triradiate

* In those cases where the species has been imperfectly described so that there is some doubt whether the cestode seen belonged to *Taenia saginata* or *T. solium*, the cestode is assigned to the species *saginata* followed by an interrogation point, as this species is the more numerous in most countries. Where the writer has failed to state the country from which the worm was collected, the locality given is that of the country in which he lived when the case was published (as far as could be determined). These doubtful localities are also marked by an interrogation point. In the last column marked "Shape of Strobila," the interrogation points indicate that the specimens were so imperfectly described that it is not certain whether they were triradiate forms or not. The dotted lines in this column indicate that the cestodes described are larval forms and hence have no strobilae.

was received, it was determined to use some of the material for feeding experiments. The writer was encouraged in the hope that the vitality of the eggs would prove unaffected by the formalin, from the fact that on several previous occasions he had fed to rabbits, proglottids which had been shipped in formalin and had always succeeded in infesting the animals. In the previous cases, however, the feeding experiments were performed as soon as the material was received.

A rabbit reared at the experiment station of the Bureau of Animal Industry was fed May, 1914, with two proglottids of the triradiate *Taenia pisiformis* already described. The rabbit died June 4, 1915. The postmortem revealed seven cysticerci, three of which were attached to the omentum, the others lying loose in the body cavity. The cysticerci were all fully grown and surrounded by a protective membrane, the largest cyst measuring 2 cm. long by 1 cm. in diameter. In dissecting out the invaginated scolices to determine the number of suckers, two specimens were mutilated and the number of suckers could not be positively determined. There is no reason to suppose, however, that more than the usual number of suckers were present. The other five specimens were entirely normal.

It can not be positively demonstrated that the rabbit was uninfested with *Cysticercus pisiformis* at the time it was fed. On the other hand, the fact that the rabbit was reared and kept in a cage until its death, and that as far as the writer is aware no rabbits from this source have been found infested with *C. pisiformis* unless as the result of feeding experiments, is very strong evidence for assuming that the cysticerci found resulted from the feeding experiment and not from a previous infestation.

The experiment therefore failed to prove that cestode larvae with an excessive number of suckers are the offspring of polyradiate adults. On the other hand, it appears that a triradiate cestode may give rise to perfectly normal larvae, which presumably would develop into normal adults. Whether or not cestode larvae with an excessive number of suckers have any genetic connection with polyradiate adult cestodes, is a question still remaining unanswered.

SUMMARY

1. The term polyradiate is used to designate those cestodes whose strobila is uniformly divided into three or more rays or wings extending throughout the entire strobila and radiating from a common axis, and whose scolices have two suckers for each of the rays present. Presumably the larvae of these polyradiate forms have as many suckers as appear in the scolices of the adults.

2. Altogether forty-four cases of polyradiate cestodes (including larvae) have been reported, in all but two of which the adult forms were triradiate. The greater number of cases are triradiate forms of *Taenia saginata*, but several species are represented and they are found in widely distributed localities. The greater frequency of this anomaly in *T. saginata* is probably due to the greater chances for observation of this species.

3. Of the two cases having more than three rays, one is apparently pentaradiate (Rosenberger's case), and the other is tetraradiate (Foster's case, the present paper); both are specimens of *Taenia saginata*. Since triradiate forms are assumed to originate from larvae with six suckers, it is suggested that the tetraradiate and pentaradiate forms originated from cysticerci having 8 and 10 suckers, respectively, larvae with this number of suckers having been found by Railliet (1899) in the case of *Coenurus serialis*.

4. The view that the origin of polyradiate forms can be traced to the ovum, is supported by the finding of oncospheres having an excessive number of hooklets. On the other hand, this view is disputed by the finding of both normal and abnormal scolices in the same coenurus. A feeding experiment with triradiate proglottids of *Taenia pisiformis* tends to show that in this species perfectly normal cysticerci may result from abnormal adults. Whether or not cysticerci with an excessive number of suckers and oncospheres with an excessive number of hooklets have any genetic connection with polyradiate adults, is a question which has not yet been solved.

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SOME NOTES AND EXPERIMENTS ON *SARCOCYSTIS TENELLA*, RAILLIET *

JOHN W. SCOTT

In a recent paper on Sarcosporidia encountered in the Canal Zone, Darling (1915) makes the interesting suggestion that the "Sarcosporidia may be side-tracked varieties of some of the Neosporidia of invertebrates which have invaded the musculature of a hospitable though by no means definitive host and are unable to continue further their life cycle and escape from a compromising and aberrant position." Darling thinks the high incidence of infection in cattle, sheep, swine, and horses favors this view, and points out the ease with which such animals may obtain Neosporidia in their food. In this connection the writer has obtained during the past year some data concerning the sheep sarcocyst that appear to favor a similar conclusion. Though the results of the experiments were negative the inferences are nevertheless interesting.

A large percentage of the range sheep of Wyoming are probably infected with *Sarcocystis tenella*. Out of sixty-five sheep examined at different times at a local slaughter house fifty were found infected, or nearly 77 per cent. In some lots approximately 100 per cent. were infected. The parasite presented the general appearance described by Railliet (1895), Alexieff (1911), and others. The stages found usually showed an alveolar structure, a few presented the pansporoblast stage, but none were in the Balbiana stage. Some of the largest cysts, and presumably the oldest ones, had the appearance of fading out or undergoing degeneration, and so far as one could observe from living material there was no indication that the parasites ever escape from the muscle of the host. The heart muscle and the esophagus were examined for the cysts, but they were found much more frequently in the heart.

Since the direct observations just mentioned gave no clue to the life history, a preliminary series of experiments was planned to test various hypothetical methods of infection. Smith (1901) has succeeded in getting a direct infection in mice by feeding muscle tissue from infected mice, and the first experiment was to determine if this method would succeed in the case of the sheep sarcocyst. While Smith's experiment might account for a natural transmission of the

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Sarcosporidia of carnivorous animals, it cannot explain transmission in the sheep, or in other herbivora. Dr. L. D. Swingle, formerly of the University of Wyoming, fed five young lambs pieces of heart muscle containing the sarcocysts. From the time they were born these lambs were fed dry feed in a dry lot and were watered from the city water supply which has its source in deep springs. When the writer examined these lambs at slaughtering time not a single one was infected. Control lambs, kept under the same conditions, were likewise uninfected. This experiment has been repeated with similar results, and it appears to show that the parasites in the sarcocysts are not in a transmissible stage or condition, using the direct method.

Several authors have held the view that an intermediate host is necessary, since the delicate structure of the spores of Sarcosporidia would ill adapt them to withstand the conditions outside of the vertebrate host. For this reason Wasielewski (1896) believes that, as in the case of the malarial parasite, an intermediate host is necessary in order to convey the parasite from one host to another. On this theory, Minchin (1903) suggests three possibilities in regard to infection by Sarcosporidia: (1) The intermediate host is a large carnivore, as the dog, in case of parasites like those of the pig or sheep; (2) after death the parasites are taken up by some carrion-feeding animal, which might be some vertebrate, as bird or mammal, or some invertebrate, as blow-fly or carrion-beetle; (3) the infection might be taken on by some internal parasite, for example, a flatworm or a nematode. Minchin regards the third explanation as unlikely, and I have frequently found lambs with no parasitic worms present, but at the same time infected with Sarcosporidia. He believes the second explanation receives some support from the extremely toxic nature of the parasites themselves, since this would aid in the death of the host.

More recently Minchin and Thompson (1915) have shown that the rat-trypanosome passes through a cycle in the digestive tract of the rat-flea, and that after this period the rat becomes infected either by licking the flea feces or by ingesting the flea. While there is no blood-sucking parasite of the sheep in Wyoming that could perform a similar rôle for *S. tenella* and at the same time account for the prevalence of this parasite, the object of the following experiment was to test whether digestion by a carnivorous animal (coyote or dog) would render the Sarcosporidia contaminative.

My second experiment, therefore, was essentially a test of Minchin's first hypothesis. On August 28 a young dog was fed liberally on sheep hearts containing sarcocysts and placed in a wire cage where the grass had not been pastured. On August 31 the dog was again fed with infected muscle, and in the afternoon of September 2 he was taken out

of the cage. By this time feces were well scattered over the grass. Water was sprinkled heavily on the grass September 3 and 9 in order to further facilitate contamination. On September 11 two lambs, previously kept in a dry lot, were placed in the cage and left for about thirty-three hours. Again October 1 two more lambs were put in the cage and left for twenty-four hours. A later examination showed that none of these lambs was infected.

Though the experiment is not conclusive, the evidence is against the idea that the digestion of muscle tissue by a carnivorous animal is the normal method by which the *Sarcosporidia* of the sheep are set free in order that they may be accessible through its own herbivorous habits. Indeed, the comparatively rare occasions on which coyotes and dogs obtain sheep's flesh would hardly account for the frequency with which flocks are infected.

During the summer of 1914 another experiment was tried that is even of more interest, and to a certain extent is a test of the second explanation suggested by Minchin. Two groups of lambs were used. Group one, consisting of twenty-one ewes and eighteen lambs, was allowed to graze in pasture A, where both dry and swampy conditions were present. In this pasture is located a permanent pond fed by seepage water, and the pond overflows except in the dry season into the swamp. The swampy portion of the pasture went dry about mid-summer. Group two, consisting of twenty-five ewes and twenty-three lambs, was allowed to graze in a small dry pasture B, where no water was present except such as fell in the frequent though scanty summer rains. At several times during the summer infected pieces of heart muscle were scattered in the pond in pasture A, and also upon the grass in pasture B. When the lambs were killed 55 per cent. of Group 1 (ten out of eighteen) were found infected, and 21 per cent. (five out of twenty-three) of Group 2. From this result it appeared (1) that lambs may become infected either through water or by eating infected grass; or, (2) which is more probable, the infection was independent of the experiment.

On the assumption that the third experiment gave positive results, it is hard to reconcile the infection of lambs in Group 2 with the results from the first two experiments. For if one does not get positive results by direct feeding of infected muscle, or by feeding grass contaminated with feces after the ingestion of infected muscle, one would not expect any infection where the muscle was simply scattered on the grass. Again, if scattering muscle containing sarcocysts on the grass or in water, and the consequent decay is a necessary condition for infective material, we are confronted with the fact that the natural death and decay of sheep carcasses will not account for all cases of infection. It

therefore appears that the infection which took place under the conditions of the third experiment was independent of the experiment. What other possibilities are left?

If we assume that the sheep is the definite host of *S. tenella* and that no intermediate host is necessary, we must conceive that the parasites are set free in the blood, find their way to the exterior in the excretions, probably in feces or urine, and that in this way food or drink is contaminated. Most authors regard this as extremely improbable and we have already stated that there is no evidence to show that the Sarcosporidia are freed in this way. Again, lambs fed along with ewes in a small dry lot must frequently have the hay contaminated with feces or urine, and yet under these conditions in the experiments no infection has so far occurred. On the other hand, if we consider an intermediate host is necessary, three possibilities arise. We may think of an external blood parasite as being the active agent in transferring the Sarcosporidia from one sheep to another; but in this case no external parasite appears to satisfy all the conditions, and we ought to get transmissions in a dry lot as well as elsewhere. Second, we may think of the intermediate host as feeding upon contaminated feces or urine and later depositing the spores on food or drink of the sheep. We can at once eliminate the matter of drink, for there was no water to be had in pasture B of my third experiment where infection occurred. While certain insects on this hypothesis might possibly account for the infection of both groups of the third experiment, it is probable that control lambs, confined with their ewes in an adjacent dry lot, would also have become infected, and we have already noted that there is no evidence that spores escape in the way suggested. The third possibility would be to assume that the intermediate host is a carrion-feeding animal. But no carrion-feeding vertebrate common to pastures A and B could be discovered. Besides, the heart muscle thrown into the shallow pond in pasture A sank to the bottom, where it was inaccessible to any sort of carrion-feeding animal, especially any insect, that might happen to be present. Minchin's second suggestion, therefore, as a possible method of infection appears to be out of the question.

If, however, the sheep is not the definitive host of *S. tenella*, but the presence of the parasite is more or less accidental, the results of the experiments given are more easily explained. First, it is evident that the conditions for infection are much more favorable in pasture A than in pasture B, though the parasites were acquired in both places. It is therefore well to consider further the difference between the two places and their similarities. In pasture B the grass was rather sparse, flowering plants were few in both numbers and kind, and various flies,

ants, beetles (under cattle dung), mosquitoes, bees (occasionally), grasshoppers, a few moths, and spiders were present. All of these things were present in pasture A, and, besides certain specific water animals, it differed from pasture B in the following particulars: There were more flowering plants, sedges were abundant in the swampy portions, mosquitoes and various flies were very abundant, and bees and moths were more frequently found. Now Erdmann (1910), Minchin (1912), and others look upon the Sarcosporidia as one group of Neosporidia, on the basis of what is already known in regard to their development and structure. If we accept their conclusions, and if according to Darling's suggestion the Sarcosporidia are aberrant Neosporidia, and infection of herbivora is acquired by accidental ingestion of invertebrate hosts or by the ingestion of the droppings of such hosts upon flowers or leaves, we can readily understand how infection took place in both pastures and how the percentage of infection in pasture A greatly exceeded that in pasture B. Further experiments are now in progress which will test the question of whether *S. tenella* is in reality only an aberrant form of one of the Neosporidia.

SUMMARY

To sum up this paper, one may say that the experiments are chiefly important for their negative significance. Infection with *S. tenella* failed to occur, (a) as the result of feeding infected muscle, (b) as the result of eating grass contaminated with feces from a carnivorous animal previously fed on infected muscle, and (c) by allowing infected muscle to decay either on dry grass or in a pond. The apparently positive results of the third experiment are best explained as due to conditions independent of that experiment. All of the evidence favors the view that the sheep is not the definitive host of *S. tenella*, and therefore is in accord with Darling's suggestion that the muscle parasites of vertebrates are aberrant forms.

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EGG VARIATION IN A TREMATODE SPECIES

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In 1903 H. B. Ward (1903a) called attention to the importance of the eggs in determining human entozoa. Later the same writer in a paper devoted entirely to the eggs of human parasites (Ward, 1908) emphasizes his earlier view and on page 180 comes to the following conclusion in regard to recorded observations of egg size: "The very existence of marked variation [in egg size] in the records of a single form is presumptive evidence that in the absence of errors of observation, two or more species are confused under the single appellation."

In all of Looss' extensive work on the trematodes he uses the size of eggs as a character of specific value, and Lühe (1909) in his summary of the fresh-water trematodes of Germany gives the egg size in his account of almost every species. These and other workers on trematodes have generally recognized the importance of determining the limits of variation and the average size of ripe, normal eggs among trematode species. On that account the following record of a considerable variation from the species average in the size of the eggs from three individuals of one of the common frog lung flukes seems worthy of note.

Recently while working on the anatomy of *Pneumonoeces similiplexus* Stafford from the lung of the leopard frog *Rana pipiens* more than two hundred eggs from ten different individuals were measured to determine accurately the average egg size for the species. The average length of the eggs for this species as computed from these measurements was found to be $37.6\ \mu$, and the range of variation showed a minimum of $34\ \mu$ and a maximum of $40\ \mu$. Later, while examining three good-sized specimens of the same species from a single frog from Oshkosh, Wisconsin, I was struck by the fact that the eggs appeared smaller than in the forms previously examined. Measurements of two hundred eggs from these individuals confirmed this opinion, since the average egg length was found to be only $34.2\ \mu$ and the limits of variation from 30 to $37.4\ \mu$. This gives a difference between the Oshkosh flukes and the normal egg average length of the species *Pneumonoeces similiplexus* of $3.4\ \mu$, or a greater difference than is found between two distinct species of this same genus, viz., *Pneumonoeces breviplexus*, with an average egg length of $22.5\ \mu$, and *Pneumonoeces longiplexus*, with an average of $24.8\ \mu$. A study of the three individuals with the

egg variation showed that in the rest of the characters used for specific diagnosis they agreed with my other specimens of *Pneumonoeces similiplexus*. This observation shows that a distinct variation may occur within a species in a character which has proved to be generally constant.

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SOME NEW GREGARINE PARASITES FROM ARTHROPODA *

MINNIE ELIZABETH WATSON

For several years I have been studying a number of gregarines parasitic in various arthropods. The literature apparently contains no record of most of them and consequently they are here described as new species. A few of the species studied were already known, but I am able to give new records on distribution and additional data on biology and life-history. Careful attention was devoted to the biology of the forms studied and extended experiments were conducted on life-history problems. In this paper is presented a brief account of these studies, which will be published in full at a later date. Especial attention is called here to the observations on movement in gregarines and on cyst formation. The descriptions of new species though concise have been worked over so carefully that it is thought they will be ample for accurate determinations.

BIOLOGICAL OBSERVATIONS

The polycystid gregarines have a septum which divides the cell into two or more distinct compartments, and the species described in this paper are all of this type. Polycystid gregarines inhabit chiefly the mid-intestines and intestinal diverticula of arthropods and are often found in large masses comprising many hundred parasites. In some genera the adult animals are solitary; in others they are attached one behind the other. Most of the latter are biassociative, but a few genera occur in chains of from three to ten or twelve individuals.

The sporonts, or adult animals, move about freely in the lumen of the intestines or lie inert between the lobes. The trophozoites, or young individuals, live either entirely within the epithelial cells, as in the family Stenophoridae, or attached to the free ends of the cells by means of variously shaped epimerites, globular in the genus *Gregarina*. When a trophozoite has absorbed sufficient nourishment from the host cell, either directly through its walls or by means of the epimerite, it breaks forth from the shriveled cell and becomes a sporont, living free in the intestine, and the useless epimerite, if present, is gradually lost. The animal now receives its food entirely by absorption of the digestive juices direct from the host intestine.

* Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 48.

Movement of the free individuals takes place by a gradual progression and by bending of any part of the deutomerite. There are two structures necessary for motion. Running crosswise in the outer part of the endocyte is a delicate network of fibrillae, the myonemes, sometimes seen with a rather low power in individuals nearly devoid of protoplasm. In the outer portion of the epicyte, the outside layer of the body, there are found very fine longitudinal striations visible only with an oil-immersion lens. In the furrows between these striations there are minute pores (Schewiakoff, 1894) through which a gelatinous material is exuded. The animal progresses by contracting a few myonemes on that side of the body which happens to be ventral and this causes a minute undulatory motion against the slide. At the same time the animal secretes mucus, which enables it to move forward against friction, much as a slug moves forward by a wave-like motion on its ventral side. The trail of mucus left on the slide is the now useless material which has gradually been pushed backward through the longitudinal furrows by the progressing animal. Bending movement is effected by a contraction and expansion of the myonemes in any part of the deutomerite.

As the beginning of cyst-formation, two individuals, either associative or solitary, commence to revolve in a large circle. If the animals are solitary, an individual is drawn into the vortex of one which has started to revolve alone. If of a biassociative type, the two commence to revolve together. The spiral gradually becomes smaller as they continue in motion and the animals come to lie in contact laterally. Motion still continues and becomes rotary. As the two sporonts are forming a compact sphere, a thick, transparent covering is being laid down on the outside of the cyst which consists of as many thin layers of gelatinous material exuded from the posterior end of the moving animals as there are rotations before the animals come to rest. The fully formed cyst, sometimes still rotating, now passes from the mid-intestine of the host to the rectum and is given out with the feces.

Finding suitable moisture, the cyst develops within from 24 to about 48 hours with the formation and growth in many genera of as many as fourteen enormously long spore ducts. Each sporont breaks up into gametes, the gametes from one sporont uniting when fully formed with those from the other to form zygotes; and when the resultant spores have become mature they are forced out violently through the spore ducts into the surrounding medium. They become scattered and if accidentally eaten by an insect of the same species as the host, the outer spore wall is dissolved in the intestine, releasing eight active sporozoites. The latter pass to the epithelial cells

and either become attached or completely embedded, when the life-cycle begins anew.

There is evidence to indicate that auto-infection may occur by the cysts ripening in the intestine, and this would account for the enormous number of parasites often found within a single host.

The arthropods from which the parasites were taken include the Diplopoda, Orthoptera and Coleoptera, and the species are grouped in this order in the text. The gregarines described are members of the following genera: *Amphoroides*, *Steinina*, *Stenophora*, *Gregarina*, and a new genus which is here designated *Leidyana*.

GREGARINES IN THE DIPLOPODA

Infection in the diplopods is fairly heavy and about three fourths of the individuals examined at Urbana were parasitized. Parasites were abundant in the early spring as well as in the fall. Some species were nearly always found to be infected, others never.

Stenophora diplocorpa n. sp. (Fig. 1): Sporonts solitary, elongate. Maximum length 360μ , width 15μ . Ratio, length protomerite: total length : : 1:16 to 1:25. Ratio, width protomerite: width deutomerite : : 1:2 to 1:3. Protomerite dome shaped, widest at posterior margin and as wide as long. Slight constriction at septum. Deutomerite slender, elongate, incompletely divided into two nearly equal parts by a crosswise constriction, widest just anterior to this constriction. Cylindrical behind the constriction and broadly rounded at posterior end. Protomerite nearly transparent, deutomerite pale tan, not opaque. Nucleus visible in vivo, situated just behind constriction in the deutomerite, spherical, and containing one karyosome. Cyst and spores unknown.

Taken at Urbana, Illinois. Host: *Euryurus erythropygus* (Brandt). Habitat: intestine.

Stenophora impressa n. sp. (Fig. 2): Sporonts solitary, ellipsoidal. Maximum length 375μ , width 48μ . Ratio, length protomerite: total length : : 1:12. Ratio, width protomerite: width deutomerite : : 1:2.3. Protomerite conical, dilated in posterior half, as wide as high. An apparent pore at anterior end. Constriction at septum not deep. Deutomerite ellipsoidal, widest through central part, posterior extremity blunt or rounded. Endocyte of protomerite nearly transparent, of deutomerite opaque. Nucleus spherical with one large karyosome. Cysts spherical, 160μ in average diameter. Spores not known.

Taken at Urbana, Illinois. Host *Parajulus impressus* (Say). Habitat: intestine.

Stenophora lactaria n. sp. (Fig. 3): Sporonts solitary, elongate, ellipsoidal. Maximum length 480μ , maximum width 39μ . Ratio,

length protomerite: total length : : 1:10 to 1:16. Ratio, width protomerite: width deutomerite : : 1:1.2. Protomerite conical, dilated above base and tapering to a point. An apparent pore at apex. As broad as high. Constriction at septum. Deutomerite ellipsoidal, widest in anterior third, tapering to an acute, rounded extremity. Endocyte of protomerite nearly transparent, of deutomerite opaque. Nucleus ellipsoidal, twice as long as wide. Cysts spherical, 150 to 170 μ in diameter. Spores not known.

Taken at Urbana, Illinois. Host: *Callipus lactarius* (Say). Habitat: intestine.

Amphoroides calverti (Crawley) (Fig. 4): Sporonts solitary, elongate. Maximum length 1670 μ , average length 1400 μ , average width 120 μ . Ratio, length protomerite: total length : : 1:47. Ratio, width protomerite: width deutomerite : : 1:2.5 to 1:3. Protomerite greatly compressed in sporonts, shallow, five times as wide as high. Deep crater within top. Constriction at septum sharp and deep. Deutomerite elongate, widest in anterior third, tapering to a sharp point. Endocyte of protomerite tan in color, not dense; of deutomerite opaque, white. Nucleus small, spherical, not visible in vivo. Myocyte well developed. Cysts spherical, averaging 380 μ in diameter. Dehiscence by simple rupture. Spores not known.

Taken at Urbana, Illinois. Host: *Callipus lactarius* (Say). Habitat: intestine.

This species was described by Crawley (1903a) as *Gregarina calverti*, but the elongate shape of the sporonts, great size, dehiscence of the cysts by simple rupture, and the fact that all the animals are solitary prove that the species is not a member of the genus *Gregarina*. I place it in the genus *Amphoroides* because of the crateriform protomerite.

GREGARINES IN THE COLEOPTERA

The following nine species have been found in beetles and beetle larvae in the two general localities mentioned. In no instance has a complete life-history been established, but the generic position is determined beyond doubt by known characters. The members of the genus *Gregarina* are superficially very similar, but a close inspection yields points of difference sufficient to indicate the individuality of each species. While the primitives of several species are similar, the satellites are dissimilar and afford one means of differentiation. The relative sizes of the species and the color and density of the protoplasm afford other means of identification. The visibility of the nucleus is important in identification. The literature has been carefully investigated in the anticipation that some of the species, especially those in

the Elateridae and the Tenebrionidae had been previously described. All are, however, new.

Gregarina katherina n. sp. (Fig. 5): Sporonts biassociative, ellipsoidal. Length of associations 96 to 150 μ . Sporonts 45 to 70 μ long, 20 to 34 μ wide. Ratio, length protomerite: total length primate :: 1:6. Ratio, width protomerite: width deutomerite :: 1:7. Protomerite of primate dome shaped, of satellite flattened. Deutomerite ellipsoidal. Nucleus spherical, one large karyosome. Epimerite large, sessile, a hyaline knob. Cyst and spores not known.

Taken at Oyster Bay, Long Island, N. Y. Host: *Coccinella novum-notata* Herbst. Habitat: intestine.

Gregarina barbarara n. sp. (Fig. 6): Sporonts biassociative, ovoidal to subspherical. Length of association (average) 250 μ . Sporonts (primites) average 145 μ long, 90 μ wide. Ratio, length protomerite: total length primate :: 1:6. Ratio, width protomerite: width deutomerite :: 1:2.2. Protomerite hemispherical in primate, flattened in satellite, six times as wide as high, deutomerite ovoidal in primate, widest part in central region. Deutomerite of satellite widest in anterior third, no constriction at septum, contour here perfectly smooth. Nucleus small, spherical, with one karyosome. Body practically transparent. Cyst and spores not known.

Taken at Oyster Bay, Long Island, N. Y. Host: *Coccinella* sp. Habitat: intestine.

Gregarina globosa n. sp. (Fig. 7): Sporonts biassociative, subglobose. Length of associations 435 μ . Length of sporonts 260 μ , width 180 μ . Ratio, length protomerite: total length :: 1:8.6. Ratio, width protomerite: width deutomerite :: 1:2.4. Protomerite hemispherical, broadest at base, no constriction at septum. Deutomerite nearly spherical. Protoplasm dense, dark gray to black in primate, lighter in satellite. Nucleus spherical. Cyst and spores not known.

Taken at Urbana, Illinois. Host: *Coptotomus interrogatus* Fab. Habitat: intestine.

Gregarina monarchia n. sp. (Fig. 8): Sporonts biassociative, elongate cylindrical. Length of associations 570 μ , width 130 μ . Ratio, length protomerite: total length :: 1:7. Ratio, width protomerite: width deutomerite :: 1:1.2. Protomerite subspherical, widest through middle portion, constriction at septum. Deutomerite elongate cylindrical, equal in width throughout, broadly rounded posteriorly. Deutomerite dense, black in transmitted light. Protomerite nearly transparent. Nucleus not visible in vivo. Cyst and spores not known.

Taken at Urbana, Illinois. Host: *Pterostichus stygicus* Say. Habitat: intestine.

Gregarina intestinalis n. sp. (Fig. 9): Sporonts biassociative, broadly ellipsoidal. Length of associations 320μ . Maximum length of sporonts 160μ , maximum width 80μ . Ratio, length protomerite: total length :: 1:5. Ratio, width protomerite: width deutomerite :: 1:2. Protomerite subspherical, widest through middle portion, deep constriction at septum. Deutomerite broadly ellipsoidal, protoplasm dense, dark gray. Nucleus not visible in vivo. Cyst and spores not known.

Taken at Urbana, Illinois. Host: *Pterostichus stygicus* Say. Habitat: intestine.

Gregarina gracilis n. sp. (Fig. 10): Sporonts biassociative, elongate ellipsoidal. Maximum length of associations 370μ ; maximum length of sporonts 190μ , maximum width 75μ . Ratio, length protomerite: total length :: 1:8. Ratio, width protomerite: width deutomerite :: 1:2. Protomerite hemispherical. Deutomerite elongate ellipsoidal. Color gray. Nucleus not visible in vivo, spherical, small, with one karyosome. Cysts average 90μ in diameter. Spores not known.

Taken at Urbana, Illinois. Host: larvae of *Elateridae*. Habitat: intestine.

Gregarina tenebrionella n. sp. (Fig. 11): Sporonts biassociative, subglobose, very small. Maximum length of association, 140μ , average length 125μ . Ratio, length protomerite: total length :: 1:4. Ratio, width protomerite: width deutomerite :: 1:1.7. Protomerite dome shaped, deutomerite nearly spherical in primate, ellipsoidal in satellite. Nucleus small, spherical. Protoplasm gray. Cyst and spores not known.

Taken at Urbana, Illinois. Host: larvae of *Tenebrionidae*. Habitat: intestine.

Gregarina fragilis n. sp. (Fig. 12): Sporonts biassociative, ellipsoidal. Length of associations 200μ . Maximum length of sporonts 110μ , maximum width 60μ . Ratio, length protomerite: total length primate :: 1:5. Ratio, width protomerite: width deutomerite :: 1:2. Protomerite dome shaped, cylindrical in posterior third. Protomerite of satellite same shape but slightly flattened anteriorly. Deutomerite ellipsoidal. Nucleus small, spherical, with one karyosome. Body practically transparent. Cyst and spores not known.

Taken at Urbana, Illinois. Host: *Coccinella* sp. Habitat: intestine.

Steinina rotunda n. sp. (Fig. 13): Sporonts solitary, globose. Maximum length 250μ , maximum width 130μ . Ratio, length protomerite without epimerite: total length :: 1:2.3. Ratio, width protomerite: width deutomerite :: 1:1.1. Protomerite conoidal, dilated

at beginning of posterior two thirds, constricted at septum. Protomerite densest in posterior half. Deutomerite spherical to obovate, posterior end either rounded or slightly pointed. Nucleus large with one large karyosome in young, with many chromatic bodies in adult. Endocyte light brown. Epimerite spherical, hyaline, persistent on large animals free in lumen of intestine. Cyst and spores not known.

Taken at St. Joseph, Illinois. Host: *Amara angustata* Say. Habitat: intestine.

GREGARINES IN THE ORTHOPTERA

Five of the following species are new, one representing a newly created genus. New distribution records and new measurements are given for three species which are already known in the literature.

Gregarina nigra n. sp. (Fig. 14).—Sporonts biassociative, cylindrical. Maximum length of associations, 1000μ . Maximum length of sporonts 530μ , maximum width 180μ . Ratio, length protomerite: total length primite :: 1:4. Ratio, width protomerite: width deutomerite :: 1:1.4. Protomerite a truncate cone angular at the free corners. Width equal to height. Widest at base, no constriction or a very slight constriction at septum. Protomerite of satellite scarcely flattened. Deutomerite cylindrical, broadly rounded posteriorly. Endocyte black. Nucleus not visible in vivo, spherical, containing many small karyosomes. Cysts and spores not known.

Taken at Urbana, Illinois. Hosts: *Melanoplus femur-rubrum* (deGeer); *M. differentialis* (Uhler); *Encoptolophus sordidis* (Burmeister). Habitat: intestine.

Gregarina stygia n. sp. (Fig. 15): Sporonts biassociative, obese. Maximum length of associations 360μ , length sporonts 180μ . Primite and satellite of approximately the same length. Maximum width of primite 100μ . Ratio, length protomerite: total length primite :: 1:6. Ratio, width protomerite: width deutomerite :: 1:1.6 to 1:2. Protomerite hemispherical in primite, flattened in satellite. Deutomerite of primite broadly ellipsoidal, nearly as wide as long; of satellite widest in anterior half, tapering slightly. Nucleus small, spherical. Endocyte dark tan but not dense, nucleus visible in vivo in both primite and satellite. Sarcocyte thicker in both protomerites than in the deutomerites. Trophozoite with a simple, small, knobbed epimerite. Cysts 150μ in diameter. Spores not seen.

Taken at Cold Spring Harbor, Long Island, N. Y. Host: *Ceuthophilus stygicus* (Scudder). Habitat: intestine.

Gregarina galliveri n. sp. (Fig. 16): Sporonts biassociative, maximum length of associations 590μ ; maximum length of sporonts 300μ , width 130μ . Ratio, length protomerite: total length primite :: 1:5.

Ratio, width protomerite: width deutomerite :: 1.1:1. Protomerite flattened, broad and low. Three times as wide as high. Deutomerite of primate vase shaped, constricted at top, widening in posterior half. Deutomerite of satellite subspherical to ovoidal. Endocyte very dense in both protomerite and deutomerite, dark brown in color. Nucleus small, spherical, not visible in vivo. Cysts spherical, 350μ in average diameter. Spore ducts numerous. Spores not seen.

Taken at Oyster Bay, Long Island, N. Y. Host: *Gryllus abbreviatus* Serv. Habitat: intestine.

Gregarina illinensis n. sp. (Fig. 17): Sporonts biassociative, elongate cylindrical. Maximum length of associations 1100μ ; length sporonts 550μ , width 180μ . Ratio, length protomerite: total length primate :: 1:5. Ratio, width protomerite: width deutomerite :: 1:1.1 to 1.5. Protomerite dome shaped, slightly constricted at septum. Deutomerite elongate cylindrical, broadly rounded behind. Protomerite of satellite cupped at top for insertion of posterior end of primate. Nucleus large, spherical, with many small chromidial bodies. Endocyte dense, black in both protomerite and deutomerite. Cysts and spores not recovered from the host.

Taken at Urbana, Illinois. Host: *Ischnoptera pennsylvanica* (deGeer). Habitat: intestine.

Gregarina achetae-abbreviatae Leidy (Fig. 18): Sporonts biassociative, obese. Maximum observed length 500μ ; average sporonts 450μ long, 225μ wide. Ratio, length protomerite: total length primate :: 1:3. Ratio, width protomerite: width deutomerite :: 1:1.1. Protomerite hemispherical to subglobose, width twice the height. Slight constriction at septum. Deutomerite stout bodied, nearly as wide as long. Widest at shoulder where it is very little wider than protomerite. Posterior end truncate. Epimerite undescribed. Endocyte dense in deutomerite, less so in protomerite. Nucleus not visible in vivo and not seen. Cysts spherical, 250μ in average diameter. Spore ducts two to five in number, of maximum length 1000μ . Spores barrel shaped, $4.5 \times 2.25\mu$.

Taken at Haverford, Pa., and Urbana, Illinois. Host: *Gryllus abbreviatus* Serv. Habitat: intestine.

Gregarina rigida (Hall) Ellis (Fig. 19): Sporonts biassociative, stout bodied. Maximum length of associations 1425μ , average length 550μ . Sporonts 250 to 750μ long, 130 to 210μ wide. Ratio, length protomerite: total length of primate :: 1:3 to 1:6. Ratio, length protomerite: total length satellite :: 1:5 to 1:16. Ratio, width protomerite: with deutomerite :: 1:1.4. Protomerite somewhat flattened, width sometimes three times the height, generally less. Constriction at septum more or less indistinct. Deutomerite cylindrical or barrel

shaped, little wider than protomerite, ending in a broadly rounded or flattened square-cornered extremity. Endocyte very dense and brownish yellow in deutomerite, tan in protomerite. Epimerite a small, spherical, hyaline knob. Cysts yellow-orange, 300μ in average diameter, spore ducts short, ten or more in number. Spores extruded in chains, barrel shaped, $5 \times 8\mu$.

Taken at Lincoln, Neb., Colorado Springs, Colo., and Urbana, Ill. Hosts: *Melanoplus femur-rubrum* (deGeer); *M. differentialis* (Uhler); *M. coloradensis* (?); *Encoptolophus sordidis* (Burm.); *Schistocerca americana* Burm.; *Melanoplus bivitattus* (Say); and *Hesperotettix pratensis* Scudder. Habitat: intestine and pyloric caeca.

This species was first described by Hall (1907) as *Hirmocystis rigida*. Crawley (1907) found it shortly after and named the species *Gregarina melanopli*. Ellis (1913) changed the name to *Gregarina rigida*.

Leidyana solitaria n. gen., n. sp. (Fig. 20): Sporonts solitary, cylindrical. Maximum length 500μ , maximum width 160μ . Ratio, length protomerite: total length :: 1:5 to 1:7. Ratio, width protomerite: width deutomerite :: 1:1.3 to 1:1.7. Protomerite conical, dilated in middle portion, constricted deeply at septum. Protomerite slightly wider than high in adults. Deutomerite cylindrical to elongate ellipsoidal, sometimes tapering, rounded posteriorly. Endocyte of protomerite pale tan, translucent, of deutomerite very dense, black in transmitted light, the two parts very plainly demarked, nucleus not visible in vivo, spherical, with one or two small karyosomes. Epimerite a large, globular, hyaline knob on a short, slender stalk. Cysts spherical, 350μ in diameter (including the transparent covering). Dehiscence by spore ducts one to twelve in number. Spores given out in chains, barrel shaped, 3 by 6μ .

Taken at Cold Spring Harbor and Oyster Bay, L. I., N. Y., Haverford, Pa., and Urbana, Ill. Host: *Gryllus pennsylvanicus* Burm. Habitat: intestine.

This species was described by Crawley (1907) under the name *Stenophora erratica*. The mode of cyst dehiscence, however, precludes the possibility of its belonging to the family Stenophoridae. I have placed it in a new genus under the family Gregarinidae, characterized as follows: *Leidyana* n. gen. Sporonts solitary, epimerite a simple globular knob, dehiscence by spore ducts, spores doliform.

I should restrict the genus *Gregarina* to biassociative sporonts only, the other characters being identical with those of the new genus.

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EXPLANATION OF PLATES 1 AND 2

Fig. 1.—Sporont of *Stenophora diplocorpa* n. sp. from camera lucida drawing of the original.

Fig. 2.—Sporont of *Stenophora impressa* n. sp.

Fig. 3.—*Stenophora lactaria* n. sp.

Fig. 4.—*Amphoroides calverti* (Crawley).

Fig. 5.—*Gregarina katherina* n. sp.

Fig. 6.—*Gregarina barbarara* n. sp.

Fig. 7.—*Gregarina globosa* n. sp.

Fig. 8.—*Gregarina monarchia* n. sp.

Fig. 9.—*Gregarina intestinalis* n. sp.

Fig. 10.—*Gregarina gracilis* n. sp.

Fig. 11.—*Gregarina tenebrionella* n. sp.

Fig. 12.—*Gregarina fragilis* n. sp.

Fig. 13.—*Steinina rotunda* n. sp., a trophozoite with epimerite.

Fig. 14.—*Gregarina nigra* n. sp.

Fig. 15.—*Gregarina stygia* n. sp.

Fig. 16.—*Gregarina galliveri* n. sp.

Fig. 17.—*Gregarina illinensis* n. sp.

Fig. 18.—*Gregarina achetae-abbreviatae* Leidy.

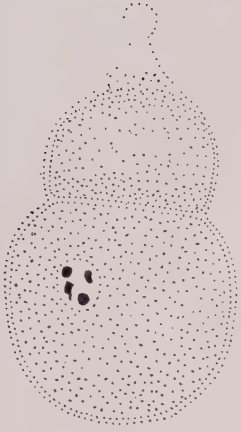
Fig. 19.—*Gregarina rigida* (Hall) Ellis.

Fig. 20.—*Leidyana solitaria* n. gen., n. sp.

PLATE 1



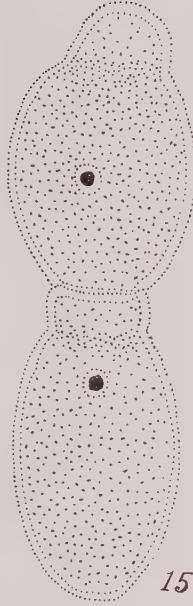
PLATE 2



13



14



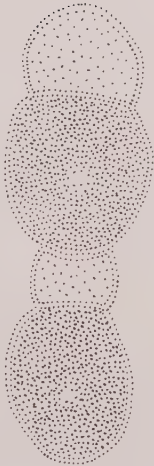
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16



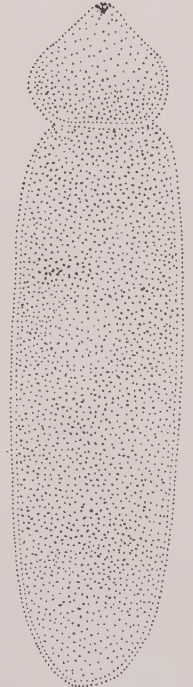
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18



19



20

PNEUMONYSSUS FOXI, NOV. SP.

AN ARACHNOID PARASITIC IN THE LUNG OF
A MONKEY (MACACUS RHESUS)

FRED D. WEIDMAN

On March 7, 1914, an adult male *Macacus rhesus* died in the Philadelphia Zoological Gardens with a subacute catarrhal colitis. Its lungs contained, in addition, sixteen to twenty small lesions about equally divided between the two organs. They were nodular, 2 to 5 mm. in diameter, were situated immediately under the pleura and slightly elevated above the same. The smaller ones were firm throughout, the larger ones with softer umbilicated centers and indurated edges. In some of the lesions smaller hard points were to be made out, suggesting a conglomerate lesion. When fresh they were pink or gray and upon incision found to contain granular gray material with granular gray walls. Upon scraping out the centers of the lesions and examining the contents, the parasitic character of the lesions was at once determined.

Microscopically, the sections of the lesions exhibit sections of an arthropod, lying in granular necrotic material, together with brownish black, extremely finely granular detritus (excrement). Around this there is a slight round-cell infiltrate, very poor in leukocytes and in close relation to a bronchus. A thick fibrous wall of very young type surrounds the whole.

The material used in making the following description was obtained by gently scraping out the interiors of two of the pulmonary lesions. This yielded, from one sac, eleven females and one male; from the other, five females. Free larvae or ova were not found. The parasites had been fixed in situ by formaldehyd 4 per cent., followed by washing in water and hardening in alcohol. Some specimens were teased, the remainder preserved entire and examined first in a watery medium, followed by clearing in glycerin-alcohol mixture, or Farrant's medium. During these studies it was found that the delicate membranes of the caroncle could only be satisfactorily examined *prior* to prolonged immersion in glycerin or Farrant's medium, both of which had a marked tendency to produce shrinkage of the same. Finer structures, such as hairs and plates, were only successfully determined after clearing for several days and examination with the oil immersion lens. All of the specimens proved to be

clearly of the same species. None were observed living, the material having been submitted subsequent to fixation.

Grossly, they were barely visible as minute, ovoid, glistening, opaque, white or faintly yellowish bodies.

THE FEMALE

Average females, unruptured and not much distorted or flattened by pressure measure as follows:—

Pubescent female	0.850 × 0.450 mm.
Ovigerous female	0.960 × 0.560 mm.
	0.940 × 0.500 mm.
	0.750 × 0.400 mm.

This gives an average of 0.875×0.478 mm. They are ovoid, the body not divided or constricted, the greatest width lying immediately behind the last pair of legs. In none of the specimens, and this also applies to the male, can the outline or even site of internal organs be made out. At most the ovum is discoverable, with occasionally the outlines of a folded embryo, in a ruptured specimen.

In one of the teased specimens dorsal and ventral plates of muscle can be made out. Each lies median, between the two middle pairs of legs. The ventral is much the heavier. It sends many fasciculi laterally to the coxae, a few radiate anteriorly to the capitulum and several posteriorly to the ends of a long, special muscle band extending transversely between the last pair of coxae. Fasciculi also radiate from the dorsal plate, a few anteriorly and many laterally to the coxae. There are other bands extending circumferentially around the posterior body half, but the condition of the specimen illustrating the muscular arrangement does not permit exact description here.

The head is continuous with the body both dorsally and ventrally. There are no eyes. The rostrum projects slightly beyond the general body contour, is triangular, the apex rounded, the lateral edges curled dorsally, but curving quickly ventrally again at the apex. In this way a short, broad longitudinal groove is produced over the dorsum of the rostrum. The hypostome is quadrilateral, save for a slight median anterior marginal peak, a little longer than broad and does not project beyond the rostrum. Its surface is finely pebbled like morocco leather. A shallow longitudinal median furrow extends through almost its whole length, stopping just short of the anterior margin. In the depths of this groove 8 to 13 short blunt teeth are noted, set in oblique manner with their points directed anteriorly and ventrally. On either side of the furrow transverse or slightly oblique muscle bundles are seen under the cuticle, which appear to pass anteriorly and median to the bases of the teeth. Midway between the furrow and the lateral hypostomal border, and well short of the

anterior margin of the hypostome, a hair is seen on each side. In addition two small papillae are present on each side of the furrow on the anterior margin of the hypostome.

The mouth parts are markedly retracted, barely projecting beyond the hypostome and not at all beyond the rostrum. The palpi lie dorsal and lateral to the mandibles. They consist apparently of three segments, of which the terminal is best seen, subspherical and capped by a stout, moderately long hair. The mandibles are chelate, lie within a sheath in which they are so far retracted as to be generally invisible. At times the two pointed, untoothed fingers of each, one shorter than the other, may barely extend beyond the mouth parts.

There are four pairs of legs, the first two geniculate. The first pair is close to, and its proximal segment (coxa) fused with, the capitulum. The second pair is close to the first pair, with no intercoxal space. The third pair is but a short distance, perhaps the width of a coxa, behind the second, and the fourth pair is at a similar distance from the third. There is no special interval separating the first and last two pairs of legs. The first three legs are subequal in length (0.22 mm.), the last one a little longer (0.25 mm.).* No legs are as long as the body width. Each leg has six articles, although at first glance they may appear to have seven or eight. This is due to the presence of the "fehlenden" muscular insertion of Winkler, which produces a ring simulating the division line between two segments. This ring appears constantly in the tarsus, is well marked constantly in the femora of the two middle pairs of legs and more faintly and only fairly constantly in the femora of the first and fourth pairs of legs. The tibia and patella are of about the same size, much shorter and heavier than the tarsus. The femur is at least twice as long as broad. The trochanter and coxa are much heavier than any of the other segments and irregularly pyramidal in form. The coxa is fully twice as broad as long, its posterior wall long, its anterior shortened by half in the last pair of legs and almost to nil in the three anterior pairs. Its ventral surface bears, distally, a cuneiform process which bears against a special chitinous plate of the trochanter. The cuticle over all segments bears long, stiff, straight or slightly curved hairs, their insertions surrounded by a low rounded ridge. They are most numerous on the distal segments and scarce but constant on the proximal ones. Spurs are constant on the three distal segments, on the other three variable.

* An ovigerous female 0.75×0.40 mm. is used for all measurements unless specially noted.

As a rule there are none on the coxae or trochanter; if present at all it is generally the first two pairs of legs which bear them.

Each leg has a special terminus. The first pair has two arched, subparallel, fairly heavy dorsal claws. Their extremities overhang or touch a single, median, compound-curved, ventral projection with a sharp point, which has the character of neither claw nor spine, appearing more like a chitinous, elongated, pointed tongue. This leg has no caroncle, the base of the claws being set directly into the substance of the tarsus.

The second pair is terminated by a short, broad caroncle measuring about twice as long as broad. It is pyriform, the handle inserted into the tarsus, the ventral and lateral distal parts open to permit protrusion of the claws, the whole now coming to resemble a hood with the opening directed ventrally. It is delicately membranous distally, and heavier proximally. Two strong claws are attached to its dorsum internally. These are parallel at their origins deep in the caroncle, but at their middles become strongly bent laterally, their tips thus coming to diverge and often to project laterally beyond the margin of the caroncle. The details in the depths of the caroncle (the handle) are uncertain. It appears that a median ventral, blunt, chitinous tooth extends from it parallel to the ventral caroncular wall and perhaps continuous with it. It may be straight or lightly curved. The margin of the proximal border of the opening shows a short, pointed, median projection.

The third pair of legs is terminated by a double hooked caroncle precisely like that of the second pair.

The fourth pair also has hooked caroncles built on the same general plan as the preceding, but they are much more slender, measuring about three times as long as broad. Its hooks, too, are much more delicate, more gracefully curved and do not, in the specimens studied, extend beyond the cavity. They are supplemented by a smaller, straighter pair deep in the caroncle, which is not always visible, probably from retraction. The median tongue or tooth is again seen here, but is much smaller, and, too, the median, marginal peak is seen at the proximal border of the caroncular opening.

The cuticle appears for the most part to be soft. It has a pebbled appearance, the elevations so low, far apart and of such irregular size (but always small) that its roughness is not at first sight apparent. In special locations it has the appearance mentioned when describing the hypostome, namely, like a very fine morocco leather. Here the elevations are very small, of uniform size, closely placed and refractile.

One such special area has already been described over the hypostome. A second lies ventrally, suggesting a sternal plate. It is median and extends from the interval between the first pair of legs to a line between the middle of the third pair. It is about three times as long as broad, subelliptical, with both ends flattened. It is not quite so sharply marked off from the surrounding integument as a plate should be. Just within its lateral margins lie six hairs. Two are directly at the anterior margin. The second pair is a little farther apart and between the second and third coxae. The third pair is separated a distance intermediate between the first and second and lies well anterior to the posterior margin of the area, that is, about opposite the middles of the third coxae. All hairs are directed posteriorly.

A third special area lies dorsally, again resembles a plate, is by far more extensive than the ventral and well marked off from the rest of the integument. It extends from a point immediately behind the rostrum to one a short distance behind the fourth coxae. It is broadly ellipsoidal except that the posterior end is roundly pointed. In its widest part it occupies the middle two fourths of the dorsum. It bears five pairs of hairs. The first pair is at the anterior margin. The second is closer behind and much closer together. The third is close behind the second, but now, again, at the lateral margins, and is the farthest apart of any of the five pairs. This brings it on a line with the posterior border of the second coxae. The interval between the third and fourth pair is about the same as that between the first and third. The fourth lies about the same distance below the fourth as that between the third and fourth pairs. These last two are very close together, being the closest of all the pairs. All of the hairs lie in the anterior two thirds of the area, the narrower posterior third being quite naked. This shield bears many small groups of pits commonly ascribed to the traction of subjacent muscular attachments. These groups are on the whole of linear arrangement, paralleling the scutal border (see plate).

The fourth special area lies around the anus. This orifice is terminal and round. In some specimens it is everted and projects beyond the general body contour. This is doubtless a pressure artefact. The special perianal area is subelliptical, with its longer dimension placed longitudinally. Three equidistant hairs lie at its margins, two lateral ventral and one median dorsal. They arch over the anal orifice. No lateral thorns are seen, although in one specimen the fracture and eversion of the anal margins by pressure gave this appearance.

In addition to the hairs which have been mentioned in connection with special areas, a dorsal pair is occasionally found at the level of the broadest part of the body posteriorly and far apart, lying well lateral to the black lines produced by the intestines. A ventral pair is also at times discoverable posterior to the plane of greatest body width. These last two pairs are not constant. Those of the three special areas are constant. All corporeal hairs are inserted in a special ring similar to the ones mentioned in connection with the hairs on the legs, and all are directed posteriorly.

There is but one pair of stigmal plates. They lie between and slightly dorsal to the third and fourth coxae and are about three times as long as broad, the narrower end directed cephalodorsad, the broader end containing the orifice. They show two or three faint curved transverse lines in imitation of segmentation.

The vulvar orifice lies ventrally in the middle of the transverse bridge joining the fourth coxae. It is longitudinal, fissural, short, and flanked by narrow, linear, chitinous plates. It appears to be continuous above with the posterior angle of a laterally elongated triangular opening whose other two angles extend far laterally along the chitinous bridge.

The intestines are indicated by two deep, black, tortuous lines extending longitudinally close to cuticle dorsally.

THE MALE

The solitary male discovered is adjudged such from its slenderer proportions (it measures 0.55×0.25 mm.), from the presence of a special anterior ventral orifice, and the lack of the vulvar orifice. In most other respects it is identical in external appearance with the female. All legs have the two dorsal hooks and one ventral piece, there is no caroncle on the first, short broad ones on the two middle ones and a longer, slenderer one on the fourth. The chelicerae in this specimen are, by chance, far extended. At most only the tips of the fingers happened to project in the case of the females. As shown in this male, each is projected from a sheath, extending a short distance beyond the hypostome. Each chelicer has a sharply pointed, lateral, longer, and median shorter, finger, both springing from a common base. The lateral one bends mesially and anteriorly, describing a compound curve. The median one curves upward.

The genital orifice of the male appears close behind the hypostome as a small circular aperture. From it a tube leads posteriorly for some distance directly under the ventral cuticle in a shelving manner, so that to superficial inspection it appears like a median longitudinal furrow.

THE LARVA

A larval form was found close to a ruptured female within which no ovum could be found, from which it is surmised that it escaped from the latter during technical manipulation. The larva measures 0.550 mm. \times 0.280 mm., is oval and has six legs, folded ventrally and with long hairs extending, tuft-like, from the distal segments. The anal plate is clearly marked and provided with three hairs.

ZOOLOGICAL POSITION

The writer places this parasite in the genus *Pneumonyssus* only tentatively and with much unwillingness. In several respects it does not agree with the generic and, furthermore, the superfamily diagnosis. In the former there should be no shields, in the latter no hypostomal armature. Following Banks' key, however, there is no alternative. It is felt that the time for a rearrangement of these endoparasitic Acarians is at hand, and in the expectation that this will be done in the near future it is deemed inadvisable to attempt to announce a new genus for this one species. It should be pointed out at this time, however, that this is the first time that a male *Pneumonyssus* has been described, and that the position of its sexual orifice places it close to, if not in, the Gamasidae. Indeed Banks has already hinted, in a personal communication, that the genus *Pneumonyssus* may belong more properly to the Gamasidae than to the Dermanyssidae, on the basis of certain features noted in the nymph of *P. simicola*.

As far as known to the writer, this is the fifth species of arachnoid described from the air passages of a monkey.

Pneumonyssus simicola was found by Banks (1904) in the lungs of a Javanese monkey (*Cyanocephalus* sp. ?) dying of opium poisoning in Java.

Pneumonyssus duttoni was found by Newstead and Todd (1906) in the trachea and bronchi of eleven Schmidt's monkeys (*Cercopithecus schmidtii*) in the Congo.

Pneumonyssus griffithi was found by Newstead (1906) in the lungs of six rhesus macaques killed in England after exposure to tuberculosis.

Pneumotuber macaci was found by Landois and Hoepke (1914) in the lungs of a *Macacus rhesus* killed in Breslau.

The description of no one of these four species agrees with this parasite or permits its inclusion in that species.

Pneumonyssus simicola has "a broad pulvillus beneath the claws in some specimens, probably females," whereas a pulvillus is constant on legs i, ii, and iii in *P. foxi*. *P. simicola* has four small bristles on dorsum, *P. foxi* has ten. With *P. simicola* bristles are not present on the coxae. On *P. foxi* they are commonly present. *P. simicola* has no dorsal plate as has *P. foxi*.

P. duttoni is at once excluded by the presence of a transverse body division, two pairs of stigmal plates and its very elongate form. It has a dorsal shield.

P. griffithi has stiliform mandibles; those of *P. foxi* are chelate. The dorsal shields of the former has six hairs, those of *P. foxi* ten. The arrangement of the groups of pores (pits) here is different, too.

Pneumotuber macaci has no shields, only one claw on dorsum of tarsi i, ii, and iii and a pulvillus on tarsus iv only. There are four dorsal hairs as against ten for *P. foxi*.

Finally, and of most importance, with none of the above species is a ventral plate or the special features of the hypostome mentioned. It is true that these are easily overlooked and may have been present in the other species, but until this is shown the parasite here described must remain a new species, though much needed future rearrangement is likely to place it in a different genus or family.

The technical description of the new species follows:

Class, Arachnoidea; order, Acarina; superfamily, Gamasoidea; diagnosis (Banks): Hypostome small, without teeth; venter without furrows; body often with coriaceous shields; posterior border never crenulate; no eyes. Family, Dermanyssidae; diagnosis (Banks): Parasitic on vertebrates; mandibles fitted for piercing; body sometimes constricted. Genus, *Pneumonyssus*; diagnosis: * A Dermanyssid; stigmal plate a little more than twice as long as broad, situated above and between the coxae of the third and fourth pairs of legs. Body without apparent shields; mouth parts retracted in the head, the palpi very short, scarcely visible; the mandibles have apparently both fingers very slender, elongate and pointed, probably used for pricking the tissues. The legs are stout and short, subequal in length, none as long as width of body, each terminated in two subequal claws. Body nearly twice as long as broad, in the male more slender. Legs with stiff bristles, but body nearly destitute of hairs.

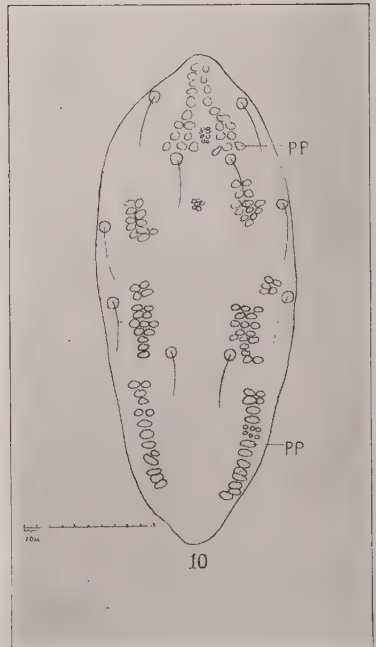
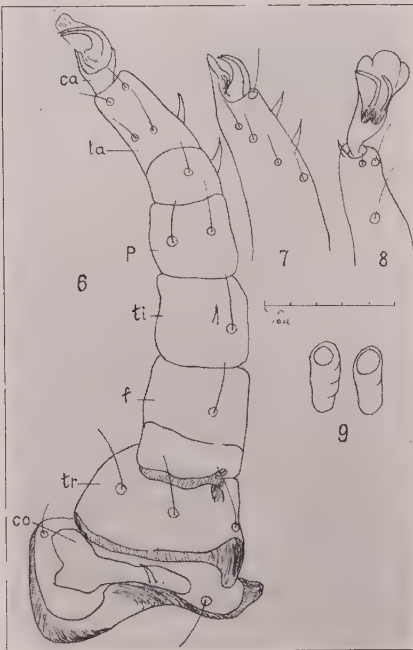
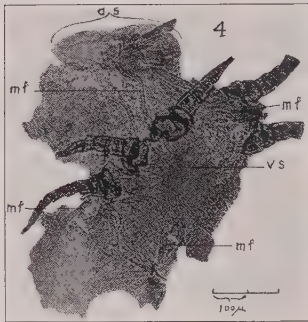
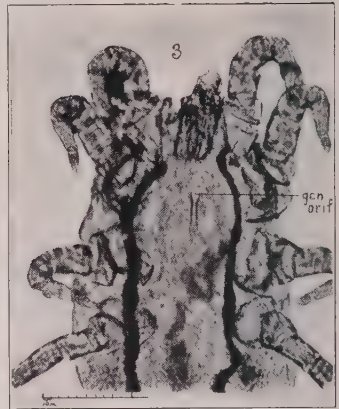
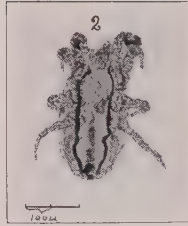
Type species, *P. simicola* Banks.

P. foxi † n. sp.; diagnosis: Adult females, yellowish white, opaque, in width a little more than half the body length. Dorsal shield with ten hairs and pitted areas, ventral with six hairs. Anal plate present with three hairs. All tarsi furnished with two dorsal claws, all except leg i with caroncle in addition; all articles hirsute and most also spinulose. Both tarsi and femora subdivided.

* Kindly furnished, together with other information, in a personal communication by Dr. Nathan Banks.

† Dedicated to Dr. Herbert Fox, who performed the autopsy upon the animal, recognized the parasitic nature of the lesions and submitted all the material to the writer for identification.

PLATE 1



Palpi of three segments, all short, the terminal one capped by a short bristle. Mandibles chelate in both sexes. One pair of stigmal plates between and dorsal to coxae iii and iv. Hypostome bears a median longitudinal row of 9 to 13 teeth, carries ten hairs anterolaterally and four anterior marginal papillae. Vulva short, median and fissural at level of coxae iv. Adult males measure a little less than half as wide as long. Sexual orifice circular and close behind capitulum. Larva hexapod, oval, 0.55×0.28 mm., bears anal plate. Length 0.875 mm., breadth 0.478 mm.

Habitat, lungs of monkey (*Macacus rhesus*).

Autopsy number P. Z. G. 3156.

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EXPLANATION OF PLATE

Fig. 1.—Ovigerous female viewed ventrally. Magnification about 66 times.

Fig. 2.—Adult (?) male viewed ventrally. Magnification about 66 times.

Fig. 3.—Same as Figure 2 but more highly magnified. Shows mouth parts and ventral shield, the latter with genital orifice and six hairs. Magnification about 240 times.

Fig. 4.—Teased adult female: *ds*, dorsal shield; *vs*, ventral shield; *mf*, muscle fasciculi. Magnification about 100 times.

Fig. 5.—Dorsal shield from Figure 4 more highly magnified; *pp*, pits; *mf*, muscle fasciculi. Magnification about 260 times.

Fig. 6.—Leg ii and iii: *ca*, caroncle; *ta*, tarsus; *p*, patella; *ti*, tibia; *f*, femur; *tr*, trochanter; *co*, coxa.

Fig. 7.—Extremity of Leg i.

Fig. 8.—Extremity of Leg iv.

Fig. 9.—Stigmal plates.

Fig. 10.—Dorsal shield. Compare with Figure 5.

CESTODE CYSTS FROM MUSKRAT

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The material was collected from a muskrat found near Washington, Pa., on Feb. 8, 1884. Four cysts were found, three embedded in the liver, and one in the peritoneum. The cysts were elliptical in outline, the largest measuring 13 by 9 mm. When opened, the contained cysticercus was seen to have developed into a strobila, with the bladder portion reduced to a small, flattened, spatulate body with collapsed walls.

The strobiles were milk-white and actively contractile. When first released they showed a tendency to thicken anteriorly so that the whole strobila became more or less clavate. Two of them, measured immediately after removal from the cysts, were 121 and 143 mm. respectively. After lying in water over night the larger specimen measured 212 mm. A few hours later it measured 300 mm. The

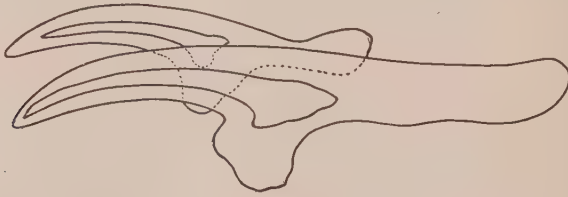


Fig. 1.—Pair of hooks. Length of longer hook 0.4 mm.

anterior end, for a distance of about 175 mm. was about 6 mm. in breadth and 3 mm. in thickness. The posterior third narrowed uniformly to 2 mm. The remnant of the bladder at the posterior end was 6.5 mm. in length and 5 mm. in breadth. When this specimen was placed in alcohol at the end of forty-eight hours it measured 325 mm.

The diameter of the scolex in a mounted specimen is 1.06 mm. The suckers are rather prominent and directed anteriorly. The portion of the scolex in front of the suckers, when the hooks are completely everted, is conical-truncate. There are two circles of hooks, those in the anterior circle being the larger. The hooks lie in pairs, a pair consisting of a large and a small hook (Fig. 1). The number of hooks, estimated from a study of living specimens, seen lateral view, was fourteen in each circle. Another specimen seen in

front view had eighteen hooks in each circle. The hooks of the anterior circle are about 0.45, and those of the posterior circle 0.26 mm. long.

Proglottids begin a very short distance back of the suckers where they are about 0.5 mm. in length. In the larger alcoholic specimen the proglottids toward the middle of the length are 5 mm. in breadth and 0.72 mm. in length; farther back the breadth is 4 mm. and the length 0.8 mm.; toward the posterior end the breadth is 3 mm. and the length 0.56 mm. Sinuous marginal vessels are visible in the stained and mounted segments, but no rudiments of genitalia were seen.

The size and shape of the hooks and the appearance of the bladder-worm indicate that this cestode is the form known as *Cysticercus fasciolaris* the larval stage of *Taenia crassicollis*.

SARCOPHAGID LARVAE FROM THE PAINTED TURTLE

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In studying the blood of vertebrates in my course in histology during the past winter, I used a specimen of *Chrysemys picta*, the common painted turtle. In pulling the right hind leg back against the plastron before making the stab for blood, I noted that a hardened cylinder partly protruded from the thigh. When the object was completely extruded, it parted in the middle and five sarcophagid larvae were discovered.



Figure 1



Figure 2

Fig. 1.—Horny case containing Sarcophagids.

Fig. 2.—Sarcophagid larva from the turtle. (Ventral aspect.)

The specimens were submitted to Dr. T. J. Headlee and to Dr. L. O. Howard. For information regarding the larvae, I am indebted to them and to Mr. C. H. Richardson, assistant state entomologist of New Jersey.

So-called bot-fly larvae have been reported by Packard (1882), True (1884), and Wheeler (1890). Wheeler corrected the previous writers and placed the larvae among the Sarcophagae. Most recently Kepner (1912) has described in detail larvae undoubtedly of the same species as my own specimens. There is no question that the tortoises are infested by sarcophagids and the reason for this brief note is found in the peculiar modification of the epidermis of the host which formed a case for the larvae.

This horny epidermal case (Fig. 1) was 15 mm. long, 5.5 mm. broad, and from 0.5 to 0.6 mm. thick. The outside was regular and smooth except at one point, where it was slightly indented. The

mouth of the case was irregular and before being disturbed the object was scarcely discernible on the skin of the turtle. The hind leg was measured, and the thigh proved to be only 25 mm. in length and 13 mm. in diameter. The leg was completely paralyzed, and although the specimen was kept alive for a month after the case had been removed, use of the leg was not regained.

The larvae (Fig. 2) were kept alive for some days, then two were placed in moist earth in an attempt to secure pupation. The results were negative, however. The other specimens were turned over to the entomology department and one of them was sent to the department of agriculture for identification. So far as the writer knows no imagoes other than the four females secured by Wheeler have been bred from the turtle-infesting sarcophagid.

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NOTES

The life-history of the human blood fluke is undoubtedly one of the most important of unsolved problems in parasitology. For many years, in fact ever since the discovery of the adult parasite in Egypt by Bilharz in 1852, this question has commanded the attention of able investigators, but practically no positive results have followed their work. Local tradition supported by circumstantial evidence led to general acceptance of the view that infection with the African species, *Schistosoma haematobium*, was acquired by bathing in infected waters. After extended study in regions of pronounced infection Looss concluded that infection took place directly through the skin and that the infecting stage was the miracidium, which underwent metamorphosis in the body of the final host, probably in the liver.

The discovery of a new human species (*Schistosoma japonicum*), was augmented by its later demonstrated occurrence in various small mammals and experimentation became possible. Utilizing this opportunity, Leiper and Atkinson recently made a trip to the East and as a result of their work, which was unfortunately cut short by the war, have published* most important studies on the life history of this fluke.

After a search lasting nearly three months and a river journey of a thousand miles, they secured a dog so heavily infected that the evacuations consisted of mucus and blood crowded with eggs. The local mollusks were placed in water swarming with miracidia and were watched to detect those species which exercised a pronounced attraction for the free-swimming fluke embryos. A small brown snail of a new genus, *Katayama nosophora*, displayed such an attraction, "The small dark head and foot speedily became festooned with little white specks and it was obvious from the agitated manner in which the snail repeatedly attempted to brush them off that their presence was a cause of considerable irritation."

In the liver of this snail were sporocysts containing cercariae with bifid tails. The cercaria had a short bifurcated gut with no trace of a pharynx. Laboratory-bred mice were exposed to infection in water containing free cercariae from the teased snail liver. At Aden on the home voyage the few mollusks living were sacrificed, and the last mouse was exposed to infection. When examined in London a month later this mouse contained live male and female blood flukes in copula in the portal vessels. These factors show conclusively that this schistosome has a life-cycle like that of the digenetic trematodes.

The cercaria is covered by minute spines, the oral sucker is enormous, equal to about one-third the length of the body, and urn shaped. Between the lateral branches of the intestine are several masses on each side, the undeveloped sex glands. The snail which functioned as secondary host though abundant proved to be entirely new.

* Brit. Med. Jour., January, 1915; China Med. Jour., May, 1915.



PROFESSOR STANISLAUS VON PROWAZEK